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Design Guidelines and Functional Specifications for Simulation of the Battlefield Management System's (BMS) User Interface

ARI Field Unit at Fort Knox, Kentucky
Training Research Laboratory

July 1988

U. S. Army Research Institute for the Behavioral and Social Sciences

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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This report provides simulation network (SIMNET) designers with a set of guidelines and functional specifications for developing a simulated interface to the Battlefield Management System (BMS) which exemplifies the vehicle-based automated command, control, and communication (C^3) systems anticipated for lower echelons of the Manuever Force. The interface includes the system's display of both text and graphic battlefield information and the display features and control functions available to the user for inputting and receiving additional C^3 data. The design guidelines and functional specification presented in this report are based on (1) formally established guidelines for interface design taken from the human factors literature and (2) the users' current estimate of their interface requirements for automated C^3 systems. The objective is to initiate the development of a simulated BMS interface that can be rigorously evaluated and modified with respect to soldier performance and training issues in the task-loaded environment provided by SIMNET.

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Human Performance and Simulation

FOREWORD

To ensure that the U.S. Army's future weapon systems are usable by soldiers, the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) investigates human performance issues related to prototype weapon systems. Simulation of weapon systems and particularly user interfaces to these systems provides ARI researchers with a medium for addressing human performance issues such as usability, training, and personnel requirements during the earliest stages of weapon system development. This report presents a set of design guidelines and specifications for developing a simulation-based prototype user interface to automated command, control, and communication (C^3) systems for lower echelon forces.

This report by the ARI Field Unit at Fort Knox was prepared under Science and Technology Task 3.5.1, "Training Requirements for NBC and the Future Integrated Battlefield." ARI's involvement in research on future battlefield conditions supports the Memorandum of Understanding between ARI and the U.S. Army Armor Center and School (USAARMC&S) on Land Battle Test Bed Research signed 9 January 1986. The Directorate of Combat Developments at Fort Knox has reviewed and approved these guidelines and specifications. The report has been provided to design engineers contracted by the Defense Advanced Research Projects Agency (DARPA) to initiate the development of a simulated Battlefield Management System (BMS) interface that can be rigorously evaluated and modified with respect to soldier performance and training issues in the task-loaded environment provided by a simulation network (SIMNET). In addition, this product was provided to representatives of the Tank Automotive Command (TACOM) and the Communications Electronics Command (CECOM) for review by system hardware engineers.

EDGAR M. JOHNSON
Technical Director

DESIGN GUIDELINES AND FUNCTIONAL SPECIFICATIONS FOR SIMULATION OF THE BATTLEFIELD MANAGEMENT SYSTEM'S (BMS) USER INTERFACE

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INTRODUCTION

The Army Research Institute (ARI) conducts applied research that focuses on meeting the people-related challenges facing the Army of today and tomorrow. As part of ARI's program to train the force, the objective of the Future Battlefield Conditions Team is to enhance soldier preparedness through identification of future battlefield conditions and the methods for training to meet those conditions (Science and Technology Task 3.5.1). Future advances in weapons and equipment of the U.S. Army, however, can increase our combat effectiveness only if those systems are usable by our soldiers. To ensure that future weapon systems are useable, ARI investigates human performance issues related to prototype weapon systems. In addition, ARI provides guidelines and specifications to initiate the development of soldier-machine interfaces that will support the empirical resolution of anticipated human performance issues. This ARI research product provides system designers with a set of design guidelines and specifications for developing a simulated user interface to the new main battle tank's battlefield management system (BMS). BMS is an integrated complex of battlefield information acquisition and processing technologies intended to significantly enhance lower echelon command and control (C^2).

ARI's primary goal in this effort is to address the human performance issues--usability, training and personnel requirements--associated with the anticipated development of automated command, control and communication (C^3) systems for lower echelon Armor units. The guidelines and specifications provided, therefore, focus primarily on the design and utility of the user interface to automated C^3 systems, and not the engineering design issues related to the actual hardware and software components of these C^3 systems. The immediate objective of this document is to formalize the requirements for simulating, not building, the user interface to automated C^3 systems.

The user interface is the soldiers' link to the capabilities and functions provided by the C^3 system. The interface includes the system's display of both text and graphic battlefield information, and the display features and control functions available to the user for inputting and receiving additional C^3 data. The design guidelines and functional specifications presented in this report are based on (1) formally established guidelines for interface design taken from the human factors literature, and (2) the users' current estimate of their interface requirements for automated C^3 systems.

The development of automated C^3 systems for lower echelon units is an iterative process that will include a series of Preplanned Product Improvements (P^3I). This document has focused on the guidelines and specifications required for simulating the operational capabilities currently anticipated for BMS. But BMS, in fact, is not expected until after a starter-set C^3 system, currently referred to as the Intervehicular Information System (IVIS), has been successfully fielded and tested. Distinctions between IVIS and BMS, which are discussed in a later section, might be summarized by describing IVIS a a degraded version of BMS.

By specifying the more advanced functions associated with BMS, rather than IVIS, a prototype automated C^3 system will be developed using simulation that allows researchers to investigate related human performance issues in both the near and mid term. It is anticipated that human performance issues related to IVIS, in the near term, can be addressed by a graceful degradation of more advanced BMS capabilities. In addition, the development of a more capable prototype will allow the Army to conduct trade-off analyses directly comparing the utility of more advanced and automated C^3 systems.

The ultimate objective of this effort is to initiate the development of a simulated BMS interface that can be rigorously evaluated and modified in a task-loaded environment such as that provided by a simulation network (SIMNET) of combat weapon systems. SIMNET is a technological innovation sponsored by the Defense Advanced Research Projects Agency (DARPA) that supports distributed, multi-player, real-time and continuous combat gaming. One version of SIMNET is called Developmental SIMNET, SIMNET-D, in which the simulator's characteristics are configured via rack mounted displays and controls that can be rapidly modified to emulate prototype weapon systems or subsystems along with their associated soldier-machine interfaces.

The BMS interface described in this document will be developed for SIMNET-D. The reconfigurable nature of simulated weapon systems in SIMNET-D will provide a medium for systematically testing and refining BMS design features and operating characteristics. In addition, this test bed will afford a medium for evaluating C^3 systems that is sufficiently (1) objective, given the automated data capture capabilities of SIMNET and (2) valid, given SIMNET's potential for assessing force-on-force combat effectiveness as a function of lower echelon command, control and communication. The soldier-in-the-loop nature of the SIMNET battlefield is ideal for evaluating both soldier performance issues and BMS related training requirements.

DISPLAY CONFIGURATION

The prototype BMS user interface must provide the user access to all of the automated command, control, and communication functions anticipated for the system, and serves as a transparent link to the various subsystems interfaced to BMS. The overall layout and configuration of the proposed BMS interface are presented in Figure 1.

As noted previously the focus of this document is BMS, an advanced prototype for automated C^3, rather than a starter-set system such as IVIS. As a near term solution to automated C^3, IVIS, for example, is not expected to provide a digital terrain data base with its associated man-made and natural terrain features including terrain elevation data critical to tactical issues of cover, concealment, and avenues of approach. Instead, the IVIS interface is expected to display a grid reference matrix as depicted in Figure 2. Related BMS enhancements not anticipated for IVIS include: color monitor; completely integrated vehicle subsystems (e.g., hull and turret network boxes, ballistics computer etc.); artificial intelligence functions for terrain analysis and mission planning; and advanced microprocessor capabilities

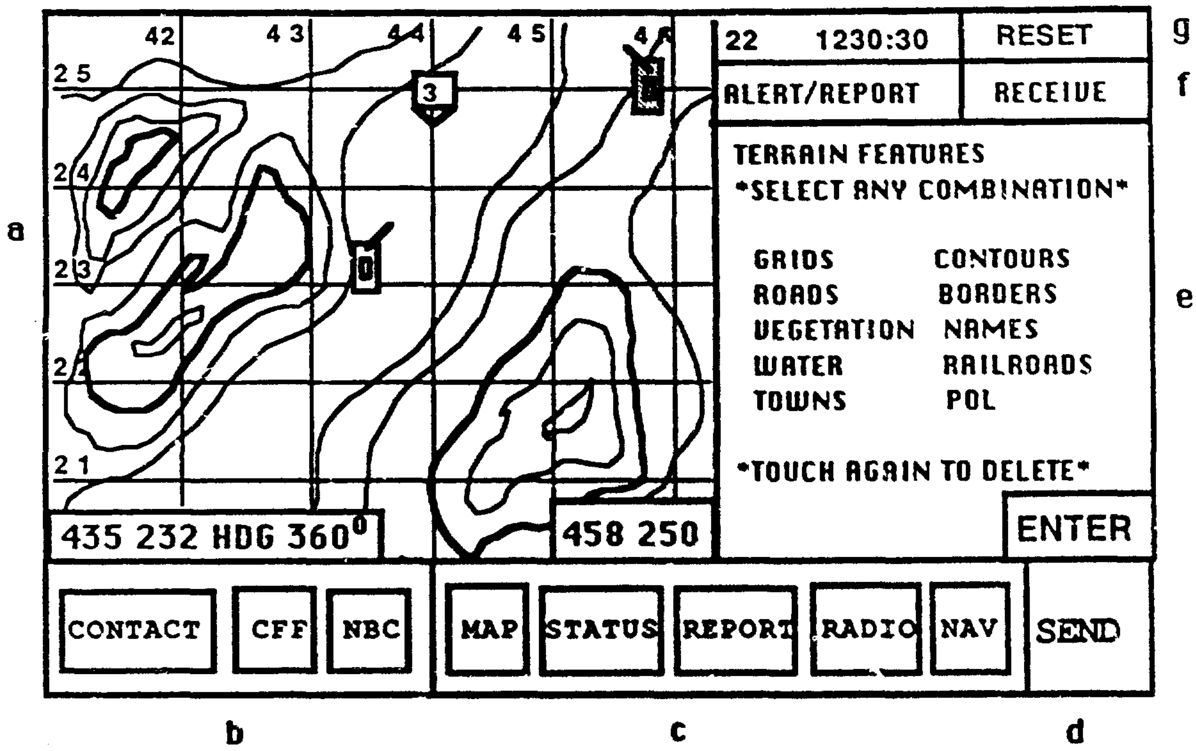

Figure 1. BMS user interface.

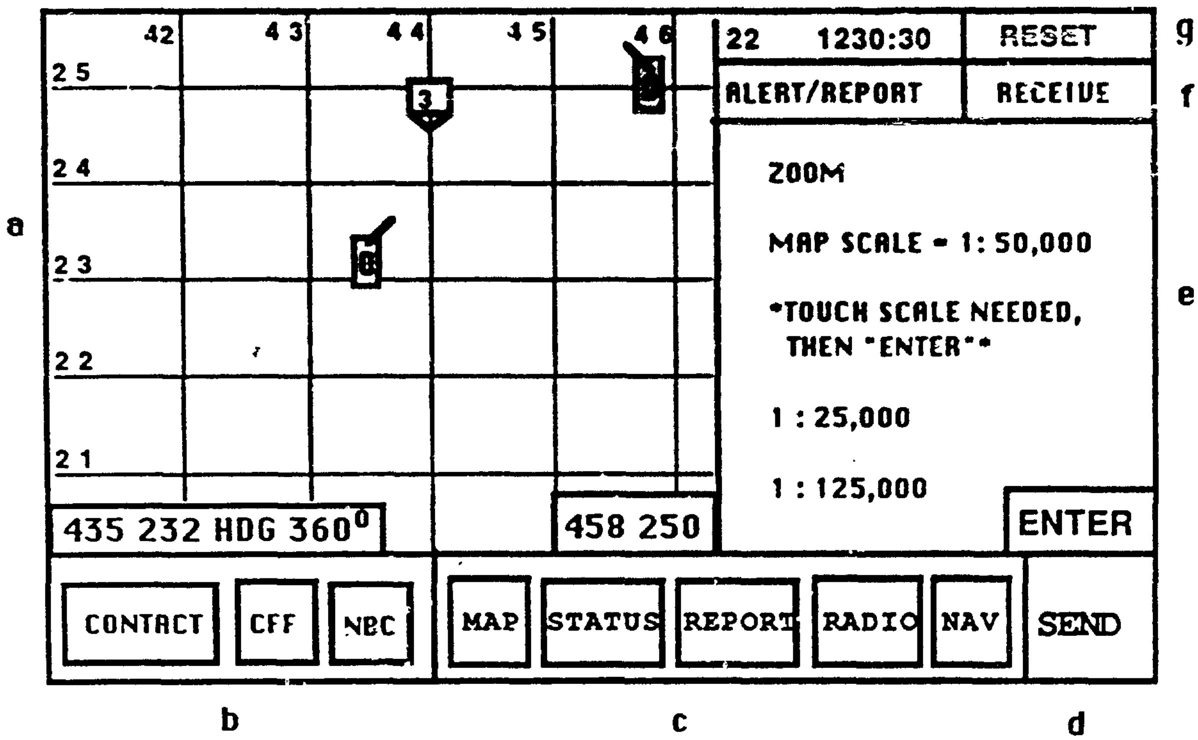

Figure 2. IVIS user interface.

for more efficient and integrated storage, processing and transmission of command and control information across all elements of the Maneuver Force.

Similarities between IVIS and BMS, however, with respect to more fundamental design guidelines and specifications are reflected by a comparison of their respective figures. The reconfigurable nature of SIMNET-D prototypes will support the graceful degradation of the more advanced BMS features and functions to evaluate IVIS specific issues when required. With this understanding, the remainder of this document will address BMS guidelines and specifications and IVIS will no longer be discussed.

As depicted in Figure 1, the BMS display is partitioned into seven distinct sections. Beginning in the upper left hand corner, the map section (a) of the display depicts a bird's-eye view of the battlefield as provided by a digital terrain data map of the area. The three sections depicted at the bottom of the display represent a series of dedicated soft switches by which the user initiates the various BMS command, control, and communication functions or annotates the map display. The three switches on the left of this row (b) are dedicated report and alert keys that allow the user to make easy, rapid inputs for each of the following critical battlefield data: contact reports; calls for indirect artillery fires; and nuclear, biological, and chemical (NBC) reports.

In the next section (c), and to the right of the dedicated report keys, are a series of controls that serve as main menu keys. Activation of these keys provides the user access to a series of submenus for the following display and control functions: map annotations or "tools" for controlling the information displayed in the map section; status menus for monitoring and reporting vehicle, subsystem, personnel and logistic data; report functions for communicating both textual and map-based battlefield data central to command and control; a radio interface for selecting and monitoring communication networks and automating call signs and authentication procedures; and a menu for updating the vehicle's position and navigation data.

The final section (d) in this row is the SEND key which provides the user the ability to transmit digitally BMS related command and control information. To prevent accidental transmissions the activation of this key should require a unique type of user input such as a one or two second continuous entry.

The relatively large section (e) on the right side of the BMS display is the variable menu area. In this region the submenus, selected by the user's activation of the main menu switches, are presented. Depending on the submenu selected, the user is provided a series of options for monitoring, updating or reporting command and control data. In addition, the variable menu area provides access to a variety of map functions that allow the user to (1) tailor his own map display or (2) prepare graphic command and control measures (i.e., operational overlays) for subsequent communications.

The section (f) immediately above this variable menu area, the message/alert section, informs the user that incoming reports, orders, warnings or other information are waiting to be received. The actual contents of these messages will be presented in the variable menu and map sections of the BMS display once the user has requested receipt of the message by touching the RECEIVE key. To prevent disruptions and ensure reception, users have requested that incoming messages should not be automatically presented (Lickteig, 1986a). The RECEIVE key is included in this section to provide the user discrete and immediate access to incoming transmissions upon request.

The section (g) in the upper left hand corner of the display, date/time, provides the user a continuous display of this information. The RESET key provides the user access to a manual update function and a menu for selecting other time related functions upon request such as alpha or zulu time codes and backward planning functions.

In addition to these seven primary subsections of the BMS display, two location windows are required. The first is an Own Location/Heading window that displays the current location of the user in six-digit coordinates (8-and 10-digit options included) and his heading in three-digit degrees (mil option included). This information is continuously updated by the Position Navigation (POSNAV) system and corresponds to the position of the vehicle as depicted on the BMS display (See POSNAV Functions). This window is located in the lower left corner of the map display. The second location window is a Point Location that displays the six-digit location of any discrete touch entry made on the map display. For example, with the entry of any waypoint, control measure, or touch contact with the map display, the six-digit coordinates of that entry should be displayed in the Point Location window which is located in lower right corner of the BMS map display. The Point Location window might only appear when the user is designating a location (e.g., unit, measure, point) on the map display. In Figures 1 and 2 it is designating the location of the enemy tank unit. Finally, Figure 3 is included to provide the reader an example of the proposed BMS interface at the currently projected size, 9-inch diagonal.

The overall configuration of the BMS display partitioned into a number of sections suggests that these are dedicated partitions which are permanently assigned in support of the functions described. A more optimal display configuration, however, might provide the option to temporarily repartition the display depending upon current activity (Brown, Burkelo, Mangelsdorf, Olsen, & Williams, 1981; Galitz, 1981) and to automatically remove interim data from the display when it is no longer needed (Martin, 1973; Newman & Sproull, 1979). For example, during lulls in the battle such as preoperation checks, initialization, or consolidation, the map area might be reduced or temporarily exchanged for an extended reporting area in the variable menu section (see Map Functions). This would reduce the layers of submenus and user inputs required for more extensive reports. Again, the soldier-in-the-loop nature of SIMNET should provide an excellent medium for exploring this and other interface issues and refining this prototype display.

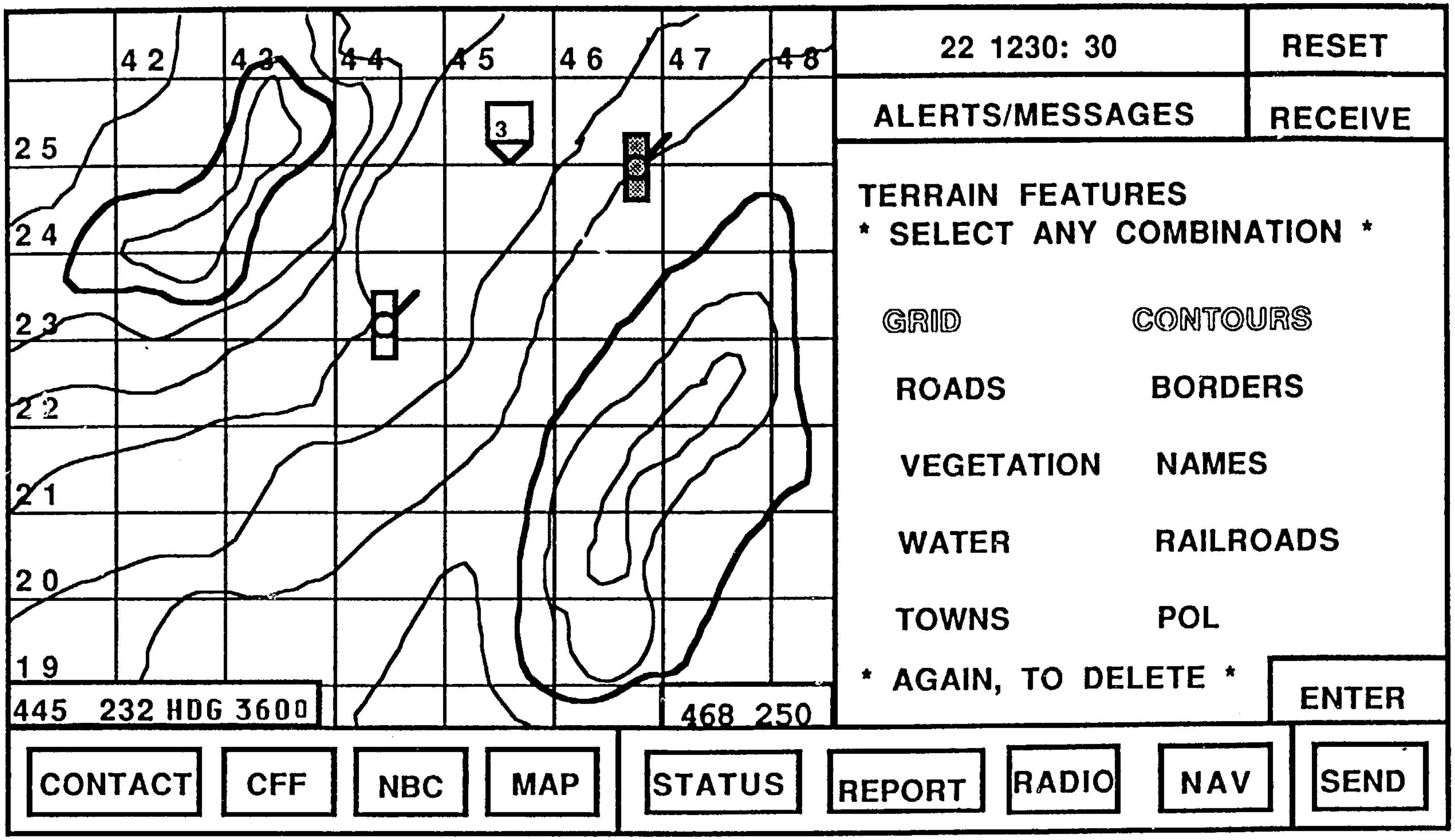

Figure 3. BMS interface at approximate 9-inch diagonal size.

DISPLAY GUIDELINES

Design Guidelines

The design of automated information management systems has received a great deal of attention during the past decade, an interest directly related to exponential increases in the availability and applicability of personal, mini, and microcomputers. This attention has resulted in numerous guidelines for the design and development of user-computer, man-machine, interfaces (Engel & Granada, 1975; Galitz, 1981; Pew & Rollins, 1975; Ramsey & Atwood, 1979; Smith, 1981; Smith & Mosier, 1984). A recent edition of Human Factors Review (Muckler, 1984), for example, includes a collection of reviews on various aspects of interface design such as visual display terminals, input media including voice technologies, dialogue modes and computer assisted instruction. These design guidelines provide a valuable base of information when designers are confronted with the need for a unique interface such as BMS which entails multiple, complex, and conflicting design requirements.

Guidelines, however, are generic--a collection of recommendations and caveats abstracted from research and experience with various, and at times differing, interface requirements. The designer must adapt these prescriptions to the unique functions, tasks, users, technologies, costs, systems, and operational environments associated with the interface being designed. In addition, utilization of design guidelines generally involves a multidisciplinary collaboration between the users who define the requirements, human factors specialists who specify an interface design that effectively integrates those requirements, and the hardware and software engineers who actually develop the interface.

User-Based Guidelines

While the specification of user interface designs and supporting functions accounts for 30-35% of all applications software (Smith & Mosier, 1984), interface designers rely on formally developed design guidelines in less than 10% of their applications (Klein & Brezovic, 1986; Tijernia, 1986). The designers interviewed by Klein and Brezovic stated that relevant design guidelines were too difficult to locate in the technical literature and the extrapolation of relevant guidelines from irrelevant data, too questionable. The work of Klein and Brezovic, Tijernia, and others demonstrates that most designs are based on mock-up or prototype interfaces and informal assessments (e.g., $n = 1$) or quasi-experimentation. The designer's preference for hands-on tests, given the difficulty of translating basic research into design applications, is not only defended--but forcefully advocated by many designers--as in Schell's (1986) recent paper: "Usability Testing of Screen Design: Beyond Standards, Principles, and Guidelines."

Similarly, the display and control features of the proposed BMS prototype are based on the user interface requirements for BMS that have been previously identified by a series of evaluations conducted by the Directorate of

Combat Developments (DCD) at Fort Knox and the Army Research Institute of Fort Knox. Prior user evaluations of prototype BMS displays have attempted preliminary identification of the BMS informational requirements (Jobe, 1986), functional requirements (Lickteig, 1986a), training requirements (Lickteig, 1986b), and operational requirements (Blasche and Lickteig, 1984). The BMS interface design specified in this document has incorporated the user-based requirements of this earlier work.

Simulation Guidelines

The following set of guidelines specify the design guidelines and functional specifications of the BMS interface, and particularly the BMS display and control requirements. Later sections are organized around the major functions of BMS and specify the menu structure, data formats, and instructional prompts required for users to execute these functions via the BMS interface. This section documents for the developers the formal guidelines employed in design of the BMS interface, and reference to the technical documentation on which these guidelines are based. In addition, these guidelines serve as a designer's template for addressing any BMS interface functions not directly discussed in this document (e.g., new or unanticipated BMS functions).

In general, the design of the BMS interface has attempted to incorporate the general human factors that apply to all man-machine interfaces including computers: consistency, brevity, flexibility, immediate feedback, and reduced operator workload (Williges & Williges, 1984). In their article on dialogue modes, Williges and Williges (1984) provide a comprehensive review of the guidelines currently available to interface designers. To extend the standardization of interface design, and afford the developers ready access to the supporting documentation, the following guidelines and specifications for simulation of a BMS prototype are organized around the content areas and guidelines provided by Williges and Williges.

Display Size

The size of the BMS display panel is constrained by the limited space available in an armored vehicle and particularly the tank. Prior work on BMS interfaces has focused on a 7- to 9-inch diagonal display. User evaluations, dependent upon the contrast and resolution of display prototypes tested, have favored the 8- to 9-inch display. It is anticipated that initially SIMNET's BMS display screen will have a minimum 12-inch screen due to the high cost of providing a smaller screen with sufficient resolution. By windowing this 12-inch display into smaller display areas, however, a reconfigurable BMS interface must allow for the assessment of alternative display sizes (e.g., 8-, 9-, or 10-inch diagonal display surfaces).

Specific guidelines are not readily available with respect to variable display sizes, and particularly, the limitations inherent to small screen displays. An assessment clearly echoed by the title of a recent review by Shannon and Stewart (1986), "Human Performance Aspects of Small Screen Displays: A Literature Review Revealing the Lack of Specific Research." The limited display size of BMS is a driving design factor, however, and so the following general guidelines are provided. Minimize the information density by presenting only information essential to the user at that time (Brown et al., 1981), and by automatically removing interim data from the display when it is no longer needed (Martin, 1973; Newman & Sproull, 1979). Users must have the capability to remove irrelevant items from the display and to reverse these decisions (e.g., selected deletion and call-up of terrain features) as noted by Barmack and Sinaiko (1966) and Ramsey and Atwood (1979). Finally, all data relevant to the user's current task should be displayed simultaneously whenever possible (Galitz, 1981).

Display Location

The actual location of the BMS interface in the tank is currently unspecified. An operational test of IVIS, the Engineer Design Test by the Contractor (EDT-C), evaluated both right-front and right-side interface locations at the commander's weapon station. The frontal location was immediately right of the gunner's primary sight extension (GPSE), and the side-mounted location was near the commander's right shoulder. Formal results of the EDT-C have not been released, but preliminary data suggest that the right-front location appeared considerably more accessible to the user for both extracting visual information from the display and inputting user command and control data. Therefore, a right-front location adjacent to the GPSE is initially recommended for SIMNET's BMS interface. In general, SIMNET-D's reconfigurability should afford an excellent test-bed for assessing the trade-offs associated with alternative locations for BMS and other tank subsystem components.

Screen Layout

Standardized locations for functional areas and display fields are specified for the BMS interface and correspond to the seven distinct subsections depicted in Figure 1. A summary of the screen layout guidelines incorporated into the proposed BMS interface is provided in Table 1. Rationales for these guidelines are presented below with reference to their documentation in the human factors literature. In general, all the BMS functional areas must remain in the same location on all frames to allow users to develop spatial expectancies and a perceptual model of the operating system (Brown et al., 1981; Engel & Granada, 1975; Galitz, 1981; Parrish, Gates, Munger, & Sidorsky, 1981). Data entry dialogues are initiated in the upper left corner of the variable menu partition (Galitz, 1981), and main function keys or commands are located at the bottom of the display (Smith, 1981). Each display page appearing in the variable menu area is titled to indicate the purpose of the page (Pew & Rollins, 1975), instructional prompts are highlighted (Brown et al., 1981; Martin, 1973), and these prompts precede the list of response options (Brown et al., 1981; Engel & Granada, 1975; Galitz, 1981).

Table 1

Screen Layout Guidelines

Standardized location--develop user expectancies, develop perceptual model of the interface.
Data entry dialogues initiated in the upper left of variable menu area.
Main function keys or commands located at the bottom of the display.
Each display page titled.
Instructional prompts highlighted.
Prompts precede the list of response options.

Color Codes

Guidelines for implementing color codes in the prototype interface are summarized in Table 2. Conventional military color coding shall be used whenever possible in the design of BMS display features such as friendly and threat units, topographic map features, and tactical control measures. Information should not be coded solely on the basis of color, however, since monochromatic displays and printers may be employed in some instances.

In general, color coding for the BMS interface is specified to direct user attention to headings, input errors, data requiring immediate attention, key data items, differentiated data groups, and particularly, items embedded in search tasks (Brown et al., 1981; Galitz, 1981; Ramsey & Atwood 1979; Williges & Williges, 1984). No more than 10 color codes or more than three hues are recommended (Engel & Granada, 1975; Ramsey & Atwood, 1979), and green might serve as the primary color used in the BMS display, with red and blue used sparingly (Brown et al., 1981). The definition or label for a colored object should be provided in a hue of the same color, and user inputs should be colored in turquoise or cyan (Brown et al., 1981).

Table 2

Color Coding Guidelines

Conventional military color coding--FM 101-5-1; FC 71-6; FC 17-17.
Direct user attention to headings, input errors, data requiring immediate attention, key data items, differentiated data groups of data and particularily for search tasks.
10 color codes, 3 hues max.
Information should not be coded solely on basis of color.
Green, primary color; red and blue used sparingly.
Cyan or turquoise for user inputs.

Table 3

Blinking Code Guidelines

Blink codes are specified for alarms, target, and object detection tasks--particularly on the map display.
2- to 3-Hz cycle with a minimum duration of 80 ms for urgent item.
3 blink codes maximum (static, slow and fast).
Blinking terminates when user has responded.
Blink codes could be made adjustable to the users scan rate.

Blinking Codes

Blink codes are specified for BMS alarms and object detection tasks (Parrish et al., 1981; Ramsey & Atwood, 1979), particularly on the map display area. More urgent warnings and alerts should be blink coded on a 2- to 3-Hz cycle with a minimum duration of 80 ms (Ramsey & Atwood, 1979). No more than three blink codes (static, slow, and fast) should be used (Barmack & Sinaiko, 1966; Engel & Granada, 1975) and blinking should be turned off when the user has responded (Galitz, 1981). Blink codes could be made adjustable to the users scan rate (Ramsey & Atwood, 1979). Designer guidelines for directing user attention via blinking codes are presented in Table 3.

Auditory Codes

Auditory signals should be used to alert and direct the users' attention to the appropriate areas of the display interface. Auditory signals should be provided as an auxiliary indication of incoming messages, alerts and warnings. The number of auditory codes used for signaling incoming information should be kept to a minimum and serve primarily to distinguish between critical and non-critical communications. Auditory signals should also be included to alert the user to system failures. While exact specification of the auditory codes to be used in the prototype are not provided, the realistic sound effects included in SIMNET provide the opportunity to evaluate differential coding patterns that may prove effective in subsequently fielded systems. In general, the designers are reminded that the optimum signal should alert the user, but not interfere with ongoing task requirements. In addition, the signal should be adjustable with respect to variable background noises, intermittent in nature to allow the user time to respond, and the user should be able to terminate non-critical signals at his discretion and in the interest of operational security (Hendricks, Kilduff, Brooks, Marshak and Doyle, 1983).

Highlighting

Brightness codes are specified for highlighting the single or next item on the display that required the user's attention or response (Engel &

Table 4

Highlighting Code Guidelines

Direct user to single or next item on the display that requires the users' attention and/or response.
10% maximum of the display highlighted at anytime.
3 levels maximum of brightness coding.
Reverse video is specified for highlighting textual data.

Granada, 1975). No more than 10% of the BMS display should be highlighted at any time (Parrish et al., 1981) and no more than three levels of brightness coding should be used (Engel & Granada, 1975; Galitz, 1981). Reverse video is specified for highlighting textual data (Engel & Granada, 1975).

Dialogue Mode

A menu-selection dialogue mode is specified for BMS and detailed in the following sections. Rationale for the menu-selection dialogue (See Table 5) was based primarily on: the need to minimize training time and user difficulties (Galitz, 1981; Parrish et al., 1981); the potential for new users (e.g., attrition, mobilization) who are unfamiliar with the BMS functions (Parrish et al., 1981); and, to support BMS's primary task of automating the fixed procedures and routine tasks required for command, control, and communication (Miller & Thomas, 1976; Smith, 1981). In addition, menu items and response options such as units and control measures should be depicted graphically whenever possible (Foley, Wallace, & Chan, 1981; Newman & Sproull, 1979).

Table 5

Rationale for Menu Dialogue Mode

Need to minimize training time and user difficulties.
Potential for new users (e.g., attrition, mobilization) unfamiliar with the system.
Need to automate fixed procedures and routine tasks.
Initial entry accuracy is critical.
Selection of graphic icons (unit and control measures) and multiple colors.

Table 6

Menu Layout Guidelines

Menu location standardized.
Each menu frame presents a list of selectable items or responses and an ENTER key for inputing the item selected.
Lists of menu items brief, arrange in separate columns, aligned and left-justified.
Multi-page option lists avoid whenever possible.
If multi-page option list is required, users able to tailor the lists (e.g., INITIALIZATION procedures for unit and control measure symbology).
Highlight most likely response option.
Control options available at any step.

Menu Layout

Menu layout is a particularly important aspect of this implementation because of the interface's small display area. Guidelines for menu layout are summarized in Table 6. Each menu frame for the BMS interface must present a list of selectable items or responses and an ENTER key for inputting the item selected (Engel & Granada, 1975; Smith, 1981). When the list of menu items is brief they must be arranged in separate columns (Pew & Rollins, 1975) and these columns aligned and left-justified (Galitz, 1981). When the list of options required for completing a report are not brief, the design may include multiple "pages," sequentially displayed report options. Multi-page option lists should be avoided whenever possible (Engel & Granada, 1975; Parrish et al., 1981; Pew & Rollins, 1975). When multi-page option lists are required, users must be allowed to preselect the options appearing on the first and subsequent pages (see specifications of INITIALIZATION procedures for unit and control measure symbology).

Menu location is standardized in the variable menu window and in the case of cursor entry, the cursor must align automatically on the most likely response option (Smith, 1981). Control options that are generally available at any step (e.g., SEND, RESET, and other dedicated functions) are input by special functions keys (Smith, 1981). One design shortcoming of the proposed BMS menu layouts is that they do not yet include overviews (e.g., wiring diagrams) that show the user his current location within a hierarchical menu structure (Smith, 1981).

Data Format

The standardized data formats of the military (i.e., FM 101-5-1 Operational Terms, Graphics and Symbology; 71-6 Battalion/Brigade Command and Control, 1 March 1985; FC 17-17, The Division 86 Tank Battalion/Task Force SOP, Coordinating Draft, July 1983; FC 17-16, The Division 86 Tank Company SOP Coordinating Draft, May 1983; and FC 17-15-3, Tank Platoon SOP, April 1985) are specified for the BMS prototype whenever applicable. This document attempts to provide developers reference to these military standards as

Table 7

Data Format Guidelines

Military standardized data formats--FM 101-5-1; FC 71-6; FC 17-17.
Critical information requirements under system, not user, control.
Data entries limited to 8-10 characters, or partitioned into smaller subgroups.
User input and system output formats same or very similar.

specific data formats are described in subsequent sections (e.g., unit and control measure symbology, report formats etc.). The format for critical information requirements should generally be under system, not user, control to ensure standardization (Engel & Granada, 1975). Data entries should be no more than 8 to 10 characters, or partitioned into small subgroups such as the grid coordinate formats specified under POSNAV functions (Galitz, 1981; Smith, 1981). Data formats for user inputs and system outputs should be the same or very similar (Smith, 1981). More general recommendations for both text and numeric data are summarized by Williges & Williges (1984).

Input Devices

Directing or pointing controls, rather than cursor controls, are specified as the primary input device for BMS (See Table 8). More specifically, a touch panel is specified over a light pen device. These specifications are consistent with recommendations that pointing control be used when item selection and position designation are the primary types of data entry (Engel & Granada, 1975; Ramsey & Atwood, 1979; Smith, 1981) which is clearly the case with BMS. Pointing controls are also highly recommended when the user-computer dialogue is menu-based (Foley et al., 1981).

For precise positioning, touch inputs must be reflected by a point designation feature (Engel & Granada, 1975; Smith, 1981) and users must be provided a fine resolution mode (see PINPOINT function under POSNAV) or the

Table 8

Touch Input Guidelines

Pointing controls recommended when item selection and position designation primary types of data entry, and user-computer dialogue is menu-based.
Touch inputs reflected by a point designation feature.
Fine resolution mode or the ability to rapidly change the scale.
System entry of user designated points and locations must require a distinct user action such as activation of the ENTER key.

ability to rapidly change the scale of the map or graphic (Engel & Granada, 1975; Foley, Wallace, & Chan, 1981). Actual entry of user designated points and locations must require a distinct user action such as activation of the ENTER key (Smith, 1981). User evaluations by DCD and ARI identified that users' prefer a touch-sensitive input device which is specified as the primary device for BMS in SIMNET-D. The touch-sensitive input device should be augmented by track ball and mouse devices to assess the differential effects of alternative input devices.

Voice inputs requiring voice analyzers would appear to be an excellent candidate for the input device if the technology were sufficiently advanced for Armor application. In the BMS setting, voice input is desirable since the users' hands and eyes are already occupied (Parrish, Gates, Munger, & Sidorsky, 1981). In addition, voice analyzers might provide automatic identification and verification of the user (Foley et al., 1981) that would enhance communication security, reduce transmission times, and decrease the users' workload. When these technologies have sufficiently matured they should be developed and evaluated as an alternative BMS input device.

Response Options

When a list of response options are made available to the user the list should be arranged in a logical order that minimizes search and response time (Foley et al., 1981; Pew & Rollins, 1975; Smith, 1981). In general, the order of multiple response options must include consideration of the following factors: information criticality; standard operating procedures (SOPs); frequency of utilization or appearance (Engel & Granada, 1975; Pew & Rollins, 1975); and in the case of extended selection lists and noncritical response times, alphabetical order (Engel & Granada, 1975; Galitz, 1981).

Display Functions

One of the primary functions of BMS is to provide users an alternative to the paper military map. Conventional map presentations are inflexible, highly codified and relatively static representations of a small surface area of the earth (Rogers and Cross, 1979). These limitations are compounded by the dynamic requirements for terrain analysis, navigation, and maneuver command and control in the Armor battlefield environment. Conventional procedures for annotating or updating map surfaces with the operational overlays required for tactical combat and planning are time-consuming and demanding. Conventional procedures for communicating this overlay information are prone to error and frequently require face-to-face exchanges in an unprotected setting.

In contrast, BMS provides users an electronic map derived from a digital terrain data base. This map can be readily tailored to the immediate area and situational requirements of the user. In addition, the BMS map can be overlayed with any combination of unit and control measure symbology, and these overlays can be generated or updated by individual users. Map and overlay information in digital format can be more rapidly, securely, and accurately transmitted to other BMS users and operators.

A primary consideration in the design of these BMS functions is to provide combat commanders a simple but powerful technology for automating many of their command and control functions. To ensure that the system is both simple and powerful with respect to the need of multiple users, from the battalion commander down to the individual tank commanders, and both experienced and inexperienced personnel (e.g., attrition, rapid mobilization), a major design principle incorporated into BMS is the user's ability to tailor the system to his level of understanding and requirements. The ability of the user to scale the electronic map to his immediate areas of interest and influence, for example, is a more obvious instance of tailoring.

The following section describes the variety of map functions and their supporting display and control features specified for the BMS prototype in SIMNET-D. Each of these functions are accessed through a series of submenus presented in response to user activation of the dedicated MAP key. All map-based reports transmitted by BMS are automatically stamped with the time and date of transmission as well as the ID and position of the reporting vehicle and the user.

Map Key

Upon user activation of the MAP key, the Map Functions submenu appears in the variable menu section of the BMS display. Figure 4 depicts this submenu and the list of map functions available to the user. Functions are listed alphabetically to facilitate the user's search among the relatively extensive set of map functions available. In addition, the Figure includes a prompt describing the required user inputs. The user selects a function by touching the function label and reverse video echoes this selection for user verification. The user inputs the selected function by touching the ENTER key and the system automatically accesses that function's supporting submenu. Each of these map functions is supported by various submenus which are described below.

It is noted that later generation BMS systems are expected to provide a more comprehensive and integrated set of functions for map utilization, and detailed terrain analysis in particular. The intent of the current effort is to specify a set of functions that meet the primary tactical requirements of the maneuver force at present, and at the same time develop the underlying tools and functions that will be needed for future systems. For example, the Route Selection, Distance, Line-of-Sight and Relief functions described below will be integrated in a more advanced system that automatically calculates, compares, and selects an optimal military route (Harris, Fuller, Dyck and Rogers, 1985). Given the user's designation of the area to be traversed or navigated, more advanced systems will automatically analyze the relative distance, cover and concealment, trafficability, and logistics to select and depict the most tactically advantageous route.

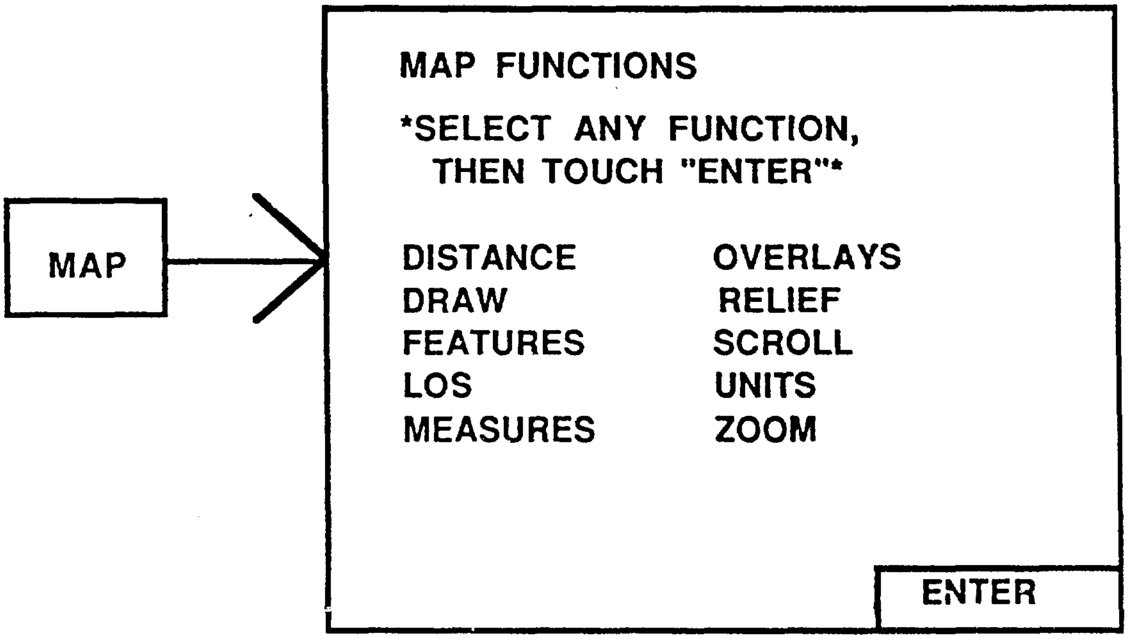

Figure 4. Map functions.

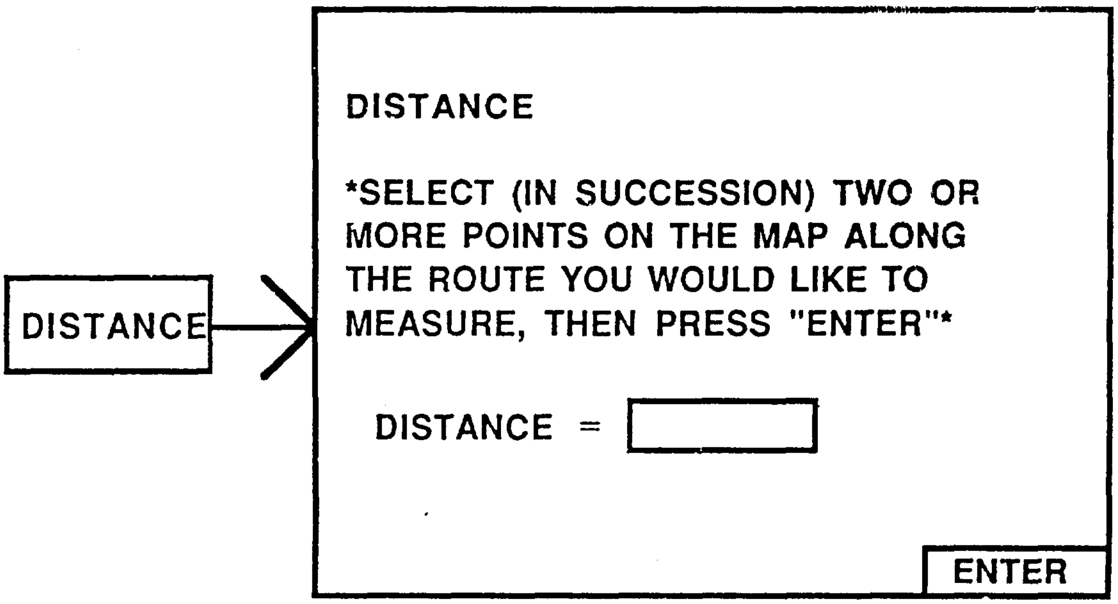

Figure 5. Distance.

Distance

This menu provides the user a function for automatically calculating the distance between any series of points selected on the map (see Figure 5). This prototype system shall require that for other than straight line calculations, the user must specify the route based on his analysis of the terrain and other tactical contingencies of interest. To determine the distance of a route the user must be able to trace out the actual course of the route onto the map display, or designate a series of points such as checkpoints which represent "legs" or segments of the route.

Draw

The Draw Function is provided as a backup function for annotating the user's map display. The use of predrawn graphics and standard military symbology such as control measures and units, as discussed below, is recommended whenever possible to ensure uniformity and intelligibility of the communications and to minimize the processing requirements of the system. At present, precise specifications of the free draw capabilities are dependent upon final selection of input devices and resolution of the interface, as previously discussed under general operating characteristics of BMS.

The Draw Function provides the user the capability to annotate his map in a free draw manner. The menu (see Figure 6) first provides a small palette of colors from which to select and then prompts the user to trace an outline of the object on the map display surface. Once the user is satisfied with the shape and location of the object drawn, the object is input into the system by activation of the ENTER key. The user is then automatically provided, as indicated by reverse lighting, an option to name or label the object by calling up a soft switch keyboard through activation of the TYPE key. This "keyboard" may require at least partial utilization of the map display area. Utilization of this map area must not occlude the object being labelled. After typing in the label for the object, the user again activates the ENTER key and the label is positioned on the map display adjacent to the object in accordance with the format specifications of FM 101-5-1. The DELETE key allows the user to erase or remove any unwanted objects along with their respective labels from the map display.

Features

This submenu provides the user a list of the various man-made and natural terrain features (see Figure 7) available on the digitized terrain data base. As suggested by the prompt, the user may call up any combination of these map features and the selections activated are again highlighted with reverse video. This selective call-up will allow users the capability to tailor their own maps and facilitate search of the map area for selected features. The capability for selective call-up of only the features of immediate interest is required. The capability to declutter the map display to a minimal subset of task-relevant features is essential to ensure that users are not

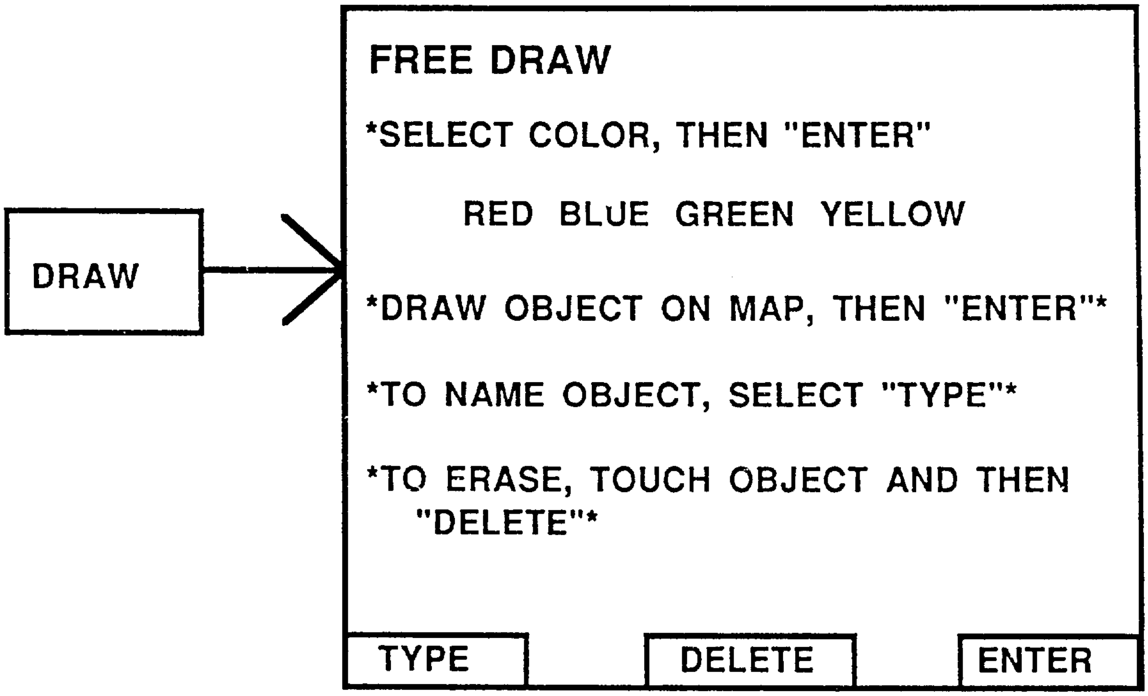

Figure 6. Free draw.

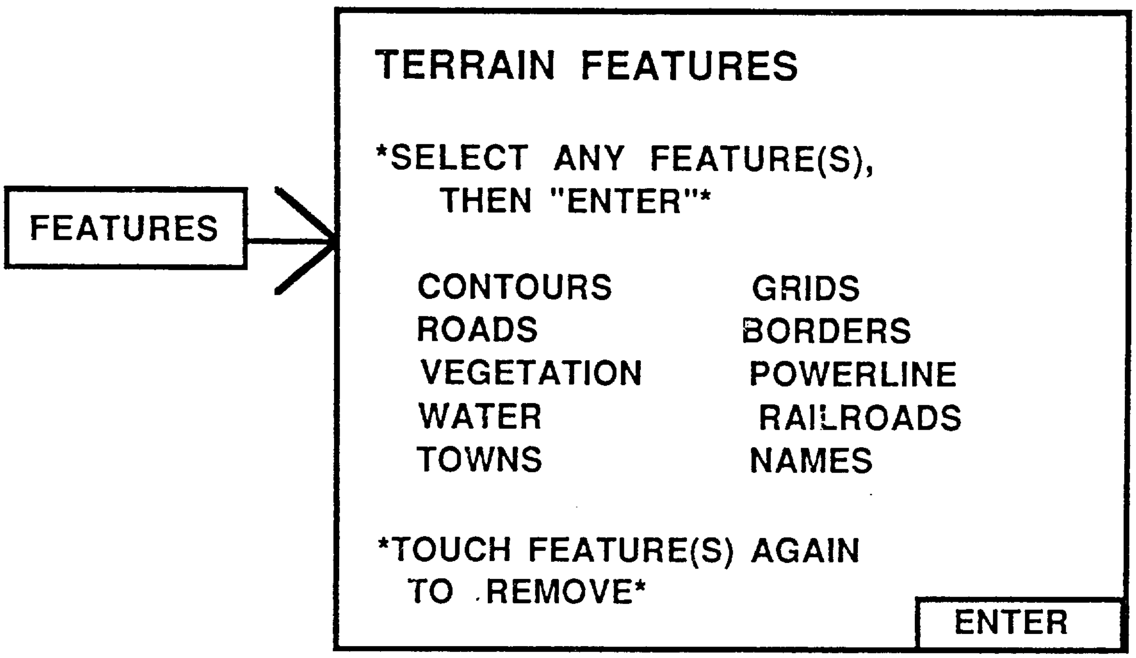

Figure 7. Terrain features.

overloaded with extraneous detail, particularly during the more intense phases of operation and engagement.

Line-of-Sight

This menu provides the user a capability to visualize the intervisibility, the ability to see one point on the ground from another point on the ground, within any area of the digital terrain data base. This is an extremely important function with respect to direct fire capability and concealment, and one of the most laborious and complex tasks required for terrain visualization and tactical planning. For prototype implementation, line-of-sight calculations will be limited to terrain and vegetation relief and not include time of day, weather, or other obscurants. The line-of-sight calculations will be of three types as depicted in Figure 8: point-to-point, area, and continuous area updates.

The point-to-point function provides the user a limited sector of intervisibility which originates from the first location designated on the map display (e.g., own or other vehicle, point on the ground) and spreads to the second location designated. While this sector provides a more limited perspective than that provided by the area function it also requires less processing by the system and allows for more rapid and detailed line-of-sight calculations.

The area function, on the other hand, provides the user a 360 degree intervisibility graphic from any point first designated on the map display extending to the radia (range) indicated by the second point designated by the user. In addition, the line-of-sight area function has a continuous update capability. For example, assuming that the user's moving vehicle is the central point of interest for intervisibility, the continuous mode automatically updates the line-of-sight calculations and displays the intervisibility graphic as a function of vehicle movement (e.g., every 100 meters). This continuous update of the area intervisibility should provide commanders a significant tactical advantage for maximizing cover and concealment during combat maneuvers.

Measures

This function provides the user relatively direct access to predrawn and standardized operational graphics for tactical annotations to the map display. The set of control measures included under this function and the symbology for these measures are again defined by FM 101-5-1 and are the same as those used for the Overlay Function which is described below. The Measures Function, however, provides the user more immediate and direct access to required elements of military symbology. The function is designed to support more timely and discrete communications such as extemporaneous operational plans (e.g., FRAGO). In contrast, the Overlay Function is designed as a more complete and integrated graphics package for more extensive planning requirements (e.g., OPORDs).

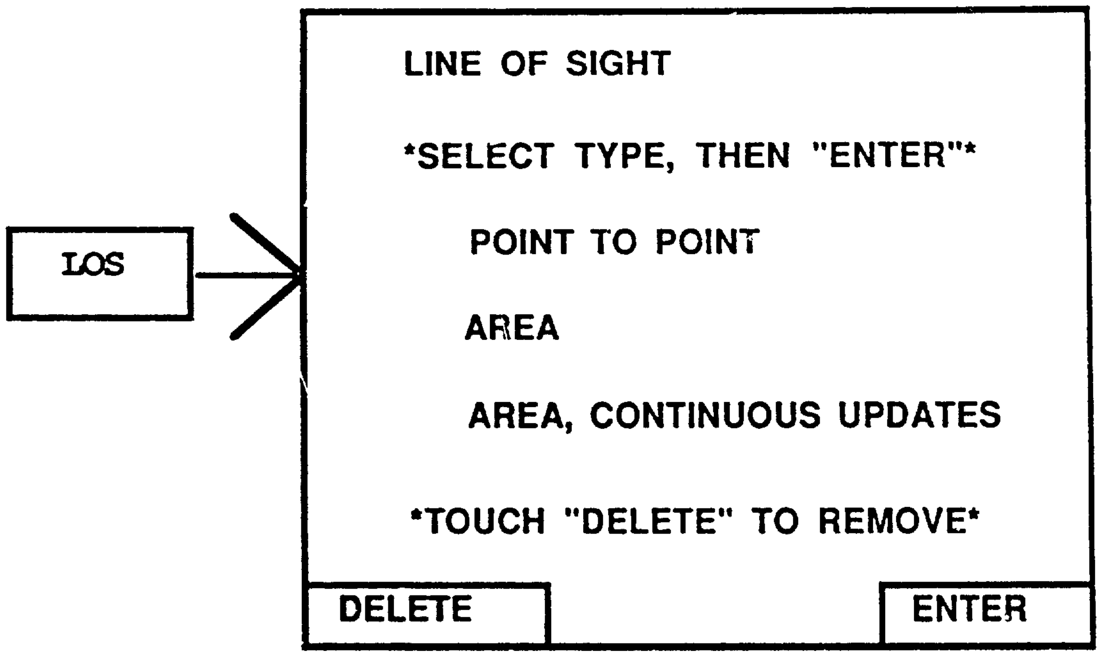

Figure 8. Line of sight.

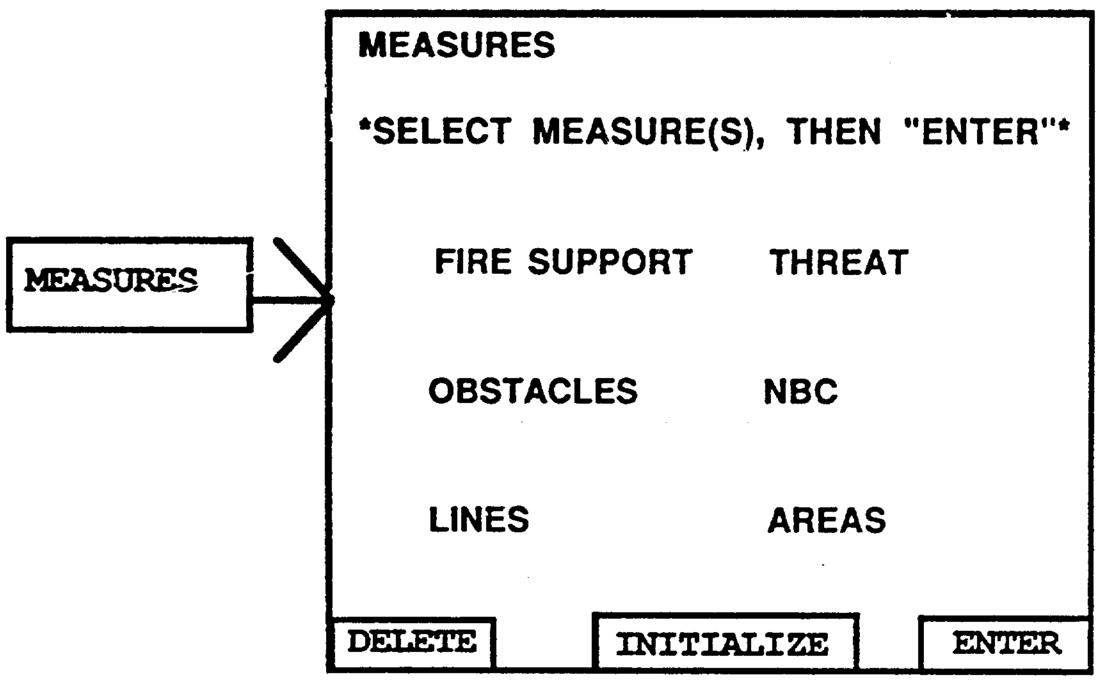

Figure 9. Measures.

Standard data formats for small unit command and control requirements are 71-6 Battalion/Brigade Command and Control, 1 March 1985 and FC 17-17 The Division 86 Tank Battalion/Task Force SOP, Coordinating Draft, July 1983. The FC 17-17 document provides a definitive reference for the data elements and formats required for measures and overlays including a breakout of the measures and color codes associated with each of the different overlays: Personnel (Red) Intelligence (Green), Logistics (Yellow), Operations (Blue) as well as Shell and NBC. Both predrawn symbology and free draw graphics created by the users must be displayed and stored in the colors appropriate to the overlays being developed.

As noted in the discussion of general BMS functional specifications, the design for the Measures Function was based on the trade-offs between the relatively limited area available on the BMS display for report and message menus and the need for simple, rapid access to graphic functions that are critical to these military communications. This function provides the user access to the entire index of military symbology included in FM 101-5-1, but requires the user to preselect a subset of these symbols for each of the control measure categories depicted in Figure 9. The user's preselection specifies the particular set of control measures to be presented in the variable menu display region upon activation of a control measure category. The user's preselection will be at least partially based on his duty position and anticipated operations in support of the mission.

Access to the FM 101-5-1 dictionary of control measure symbology and the preselection process are initiated by pressing the INITIALIZATION key displayed in Figure 9. While complete specification of the initialization process and supporting menu structures are beyond the scope of this document, it is noted that this initialization is expected to occur prior to actual combat operations as part of the commander's weapon station preparation. Given this preoperational status, the map display region will be temporarily transformed to an extended dictionary display region to allow the user to readily search and select from the dictionary's contents.

As with all user inputs, range control fields will automatically notify the user of input values that exceed any anticipated boundaries (e.g., display areas for variable menu and/or map display). For this pre-selection process for example, the system will notify the user when the number of control measures selected (e.g., 6-10 measures) exceeds the immediate menu area available to the system. The user will then have the option of adding or deleting any measures to this primary subset, followed by the option to select a secondary subset, and any additional subsets required. The user's preselections are then permanently stored until reinitialization is requested. In addition, the system should have the capability to provide default selections for each category of control measures by lower echelon duty positions.

The user's activation of the Measures key from the Map Functions menu (Figure 4) immediately accesses the list of control measure types depicted in Figure 9. Selection and entry of one of these types of measures leads directly to a submenu of the various measures requested. The set of control measures appearing under this category corresponds to those preselected by the user during the initialization process (or default values provided for the duty position of the user). The submenu of Lines, Points, and Boundaries (see Figure 10), for example, provides the user's preselected control measures for this category such as platoon, company, and battalion boundary measures and several instructional prompts about how to superimpose these measures onto the user's map display.

As indicated by the instructional prompts, the user first selects the particular control measure required, with his selection being reflected by reverse video of that measure in the variable menu area, and then touches the map display at the location(s) the measure is needed. A blinking graphic of the measure appears at that location and the six digit location of the measure's center appears in the Point Location window. For measures requiring more than one localization point, such as phase lines and boundaries, the system verifies input of the first point with a blinking cursor and awaits input of the remaining points before depicting a blinking graphic of the measure selected. If the user is satisfied with this location, the measure is then input into the data base by pressing the ENTER key at which time the graphic of the measure stops blinking.

As indicated by the next prompt, the user can change the orientation of the measure, the system's default orientation is North, by retouching the map in the direction desired, and the system verifies this request by immediately realigning the blinking icon of the measure in the direction indicated. If the user is not satisfied with the orientation, retouching the map will repeatedly change the orientation. When satisfied with orientation, the user inputs the measure's orientation by pressing the ENTER key and the measure stops blinking.

The user is then automatically provided, as indicated by reverse lighting, an option to name or label the object by calling up a soft switch keyboard through activation of the TYPE key. As noted previously the "keyboard" may require at least partial utilization of the map display area. Utilization of this map area must not occlude the measure being labelled. After typing in the label for the measure the user again activates the ENTER key and the label is positioned on the map display adjacent to the measure in accordance with the field specifications of FM 101-5-1. The DELETE key allows the user to erase or remove any unwanted measures along with their respective labels from the map display.

Additional measures which are included in the user's primary set are available to the user. They may be added by repeating the same sequence of steps as above as indicated by the final prompt. Alternate subsets of control measure symbology, preselected by the user, can be accessed by pressing the MORE key. These subsets will displace the primary set in the variable menu area in the order they were constructed by the user. The procedures for inputting these measures onto the map display are the same as those for the primary set.

Each of the additional types of control measures specified in FM 101-5-1 must be supported by similar submenus and procedures. Although these are not further detailed in this document, the submenu for the Objectives, Areas,

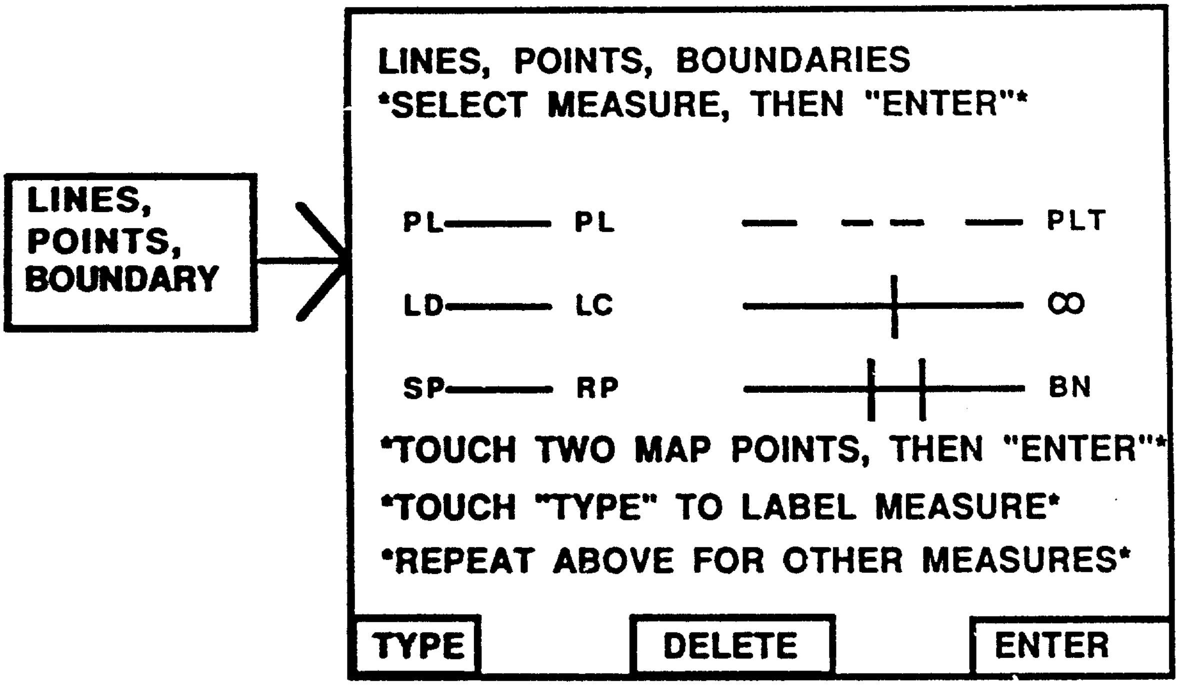

Figure 10. Lines, points.

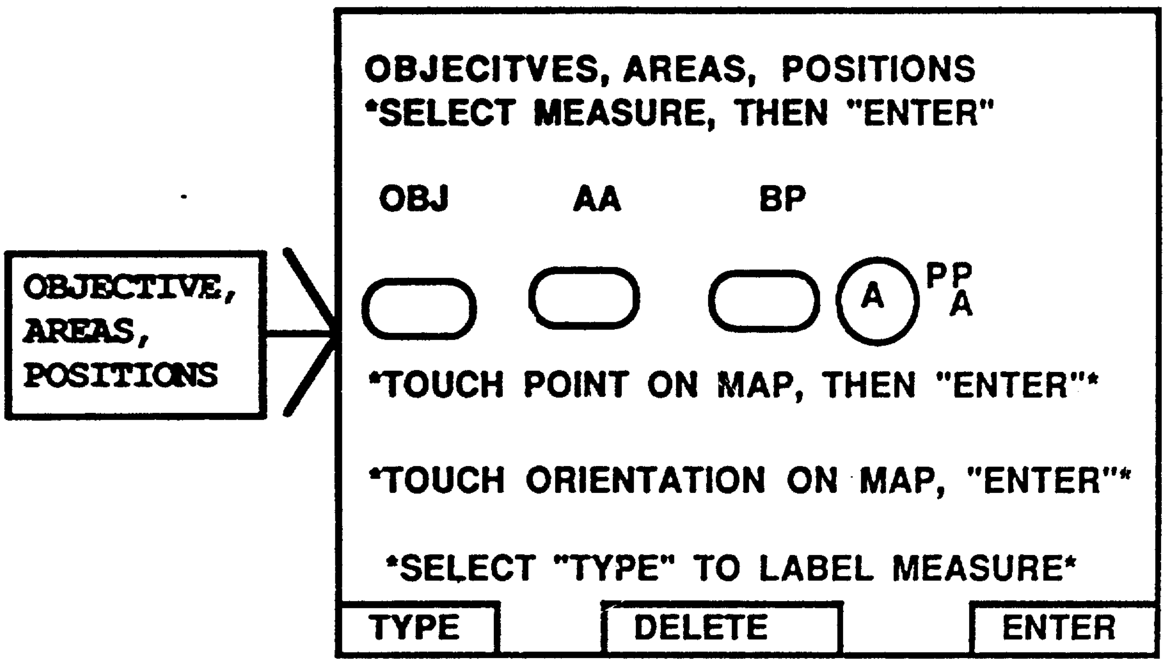

Figure 11. Objectives, areas, positions.

and Positions (see Figure 11) provides a sample of the various control measures and supporting procedures required for the remaining types of control measures.

Overlays

This menu provides the user a list of the major types of tactical overlays (see Figure 12) to be reviewed, created, or revised. As suggested by the first prompt the user may select, by pressing the overlay type(s) needed, any combination of overlays to review or inspect. Selections are verified by reverse video and after pressing the ENTER key, the most recently stored overlay(s) will be superimposed over the map display.

If the user has selected an overlay that does not at least partially overlap the map region currently depicted, the system will provide the user an indication of this incongruity on a new menu screen that is automatically accessed and returns a list of options to the user (see Figure 13): (1) the map area may be adjusted to coincide with the overlays(s) requested; (2) the user may turn the map off temporally and the overlay(s) selected will be displayed in the map display area; (3) the user can request a list and the location of all stored overlays of the type requested; or (4) the user can return to the previous menu and the request to review the overlays will be terminated.

If the overlay(s) selected corresponds to the user's map area currently displayed, the system assumes the user may need to update the overlay(s) and automatically presents the Measures Functions (see Figure 9) in the variable menu area. The user then designates the type of control measure to be added or deleted to the overlay by using the same series of inputs previously described for the Measures Functions. When the user has completed the updates to the overlay he can directly store the updates by pressing the ENTER key, or rename the overlay by pressing the TYPE key.

As for the Draw Function, the user is then automatically provided, as indicated by reverse lighting, an option to name or label the overlay by calling up a soft switch keyboard through activation of the TYPE key. This "keyboard" may require at least partial utilization of the map display area. Utilization of this map area must not occlude the overlay being labelled. After typing in the label for the object the user again activates the ENTER key and the label is positioned on the map display adjacent to the overlay in accordance with the field specifications of FM 101-5-1. The DELETE key allows the user to erase or remove any unwanted overlays along with their respective labels from the map display.

If the user pressed the MAKE overlay key, rather than the REVIEW/UPDATE key, the system assumes the user's map corresponds to the area of interest and the system proceeds immediately to the presentation of listing the Measures Functions (see Figure 9) in the variable menu area. Again the user then designates the type of control measure to be added to the overlay by using the same series of inputs previously described for the Measures Function, and the next submenu immediately accesses the set of control measures of overlay requested by the user. When the user has completed construction of the over-

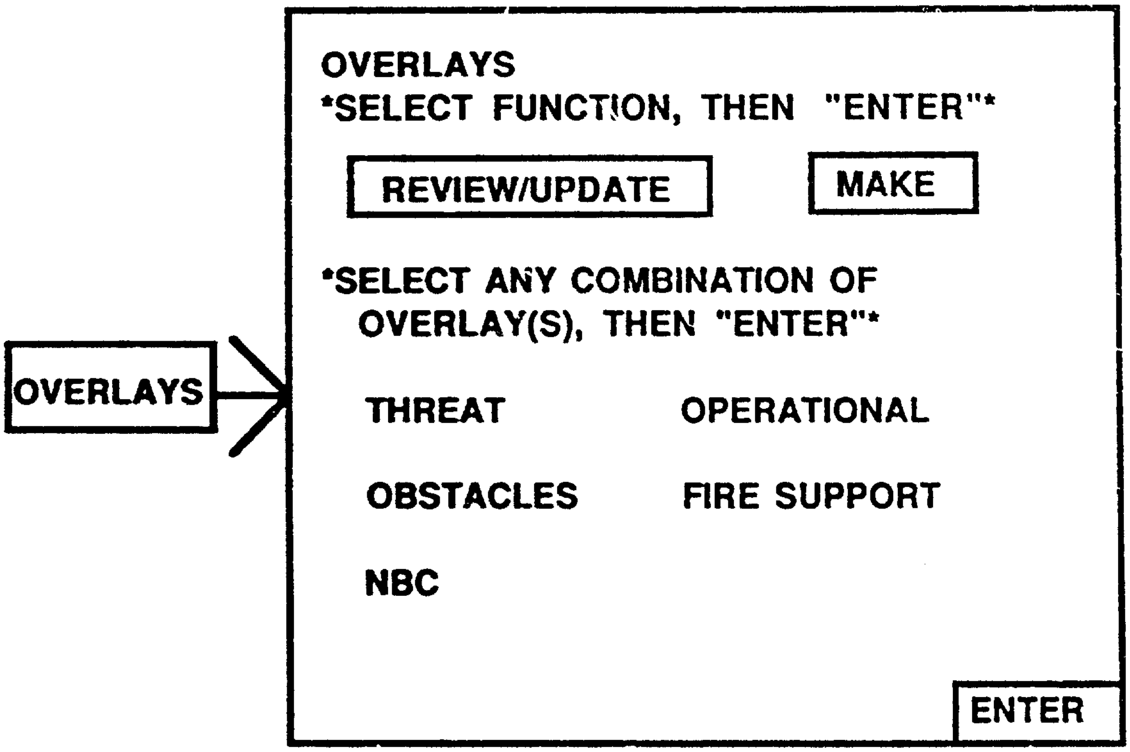

Figure 12. Overlays.

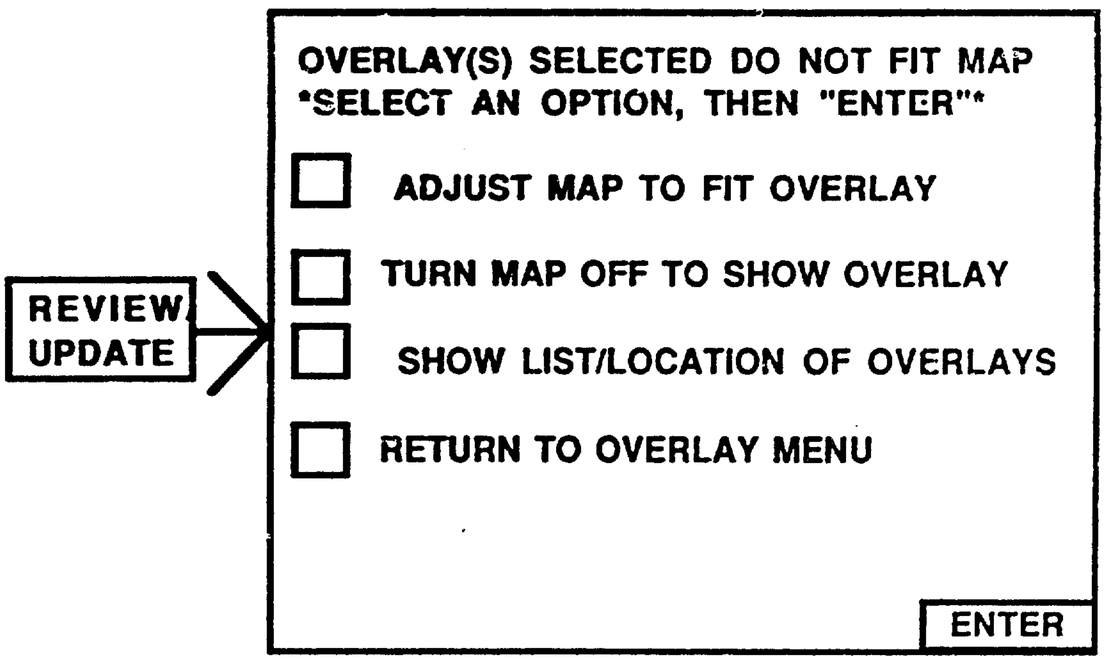

Figure 13. Review/update.

lay he can name the overlay by pressing the TYPE key to access the keyboard and then directly store this new overlay by pressing the ENTER key.

Relief

This submenu provides the user the capability to view a cross-section of the terrain (see Figure 14). By touching any two points on the map, the terrain relief between these points is presented on the map display. This presentation must not occlude the terrain region being viewed in relief. The user's designated points on the map must remain verifiable to the user while completing the immediate task, which in this case is comparing this cross-section with the area designated. The cross-section display must also provide frame-of-reference cues (e.g., quantification of the discrepancies in elevation being inspected).

Scroll

This menu allows the user to extend his view of the terrain beyond the immediate area being displayed on the system. As directed by the prompt the user touches the map area he would like to see and this location is scrolled to the center of the screen. The rate of scroll must be slow enough to allow the user to maintain his frame of reference and relative location. The own vehicle icon maintains its current location which is no longer centered on the display and begins blinking to better ensure the user can readily detect his own vehicle location. The scroll can be repeated by again selecting a new location to be moved to the center of the map display. If the scroll results in the displacement of the vehicle from the display, a blinking arrow will be presented at the edge of the map that corresponds to own vehicle heading and own vehicle distance (displacement in kilometers) from the center of the map will be presented adjacent to the heading arrow.

It is noted that this manual scroll function is different than the automatic scroll of the map that occurs during own vehicle movement. For this automatic scroll the own vehicle icon remains in the center of the map display and the map appears to move under the vehicle. In addition, the system provides the user a Zoom Function described below that allows him to change the scale of the map (1:125,00; 1:50,000;1:25,000) to quickly review a larger area of the terrain by moving to a scale smaller than the scale currently employed. Unique to the manual scroll, however, is the user's ability to view in greater detail (i.e., 1:50,000; 1:25,000) any region of the terrain included in the system's terrain data base.

Units

This function provides the user access to predrawn graphic symbology for depicting on his map display both friendly and threat units and installations. Assuming multicolor capabilities, blue or black will be used for all friendly units, posts, installations, and equipment and red for corre-

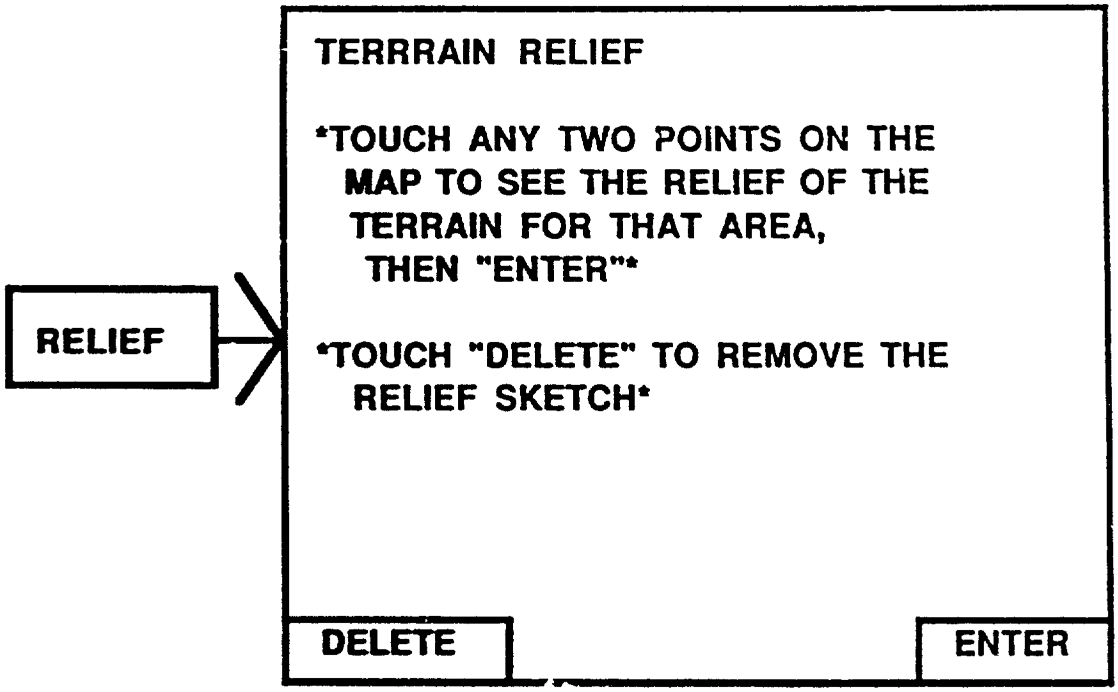

Figure 14. Terrain relief.

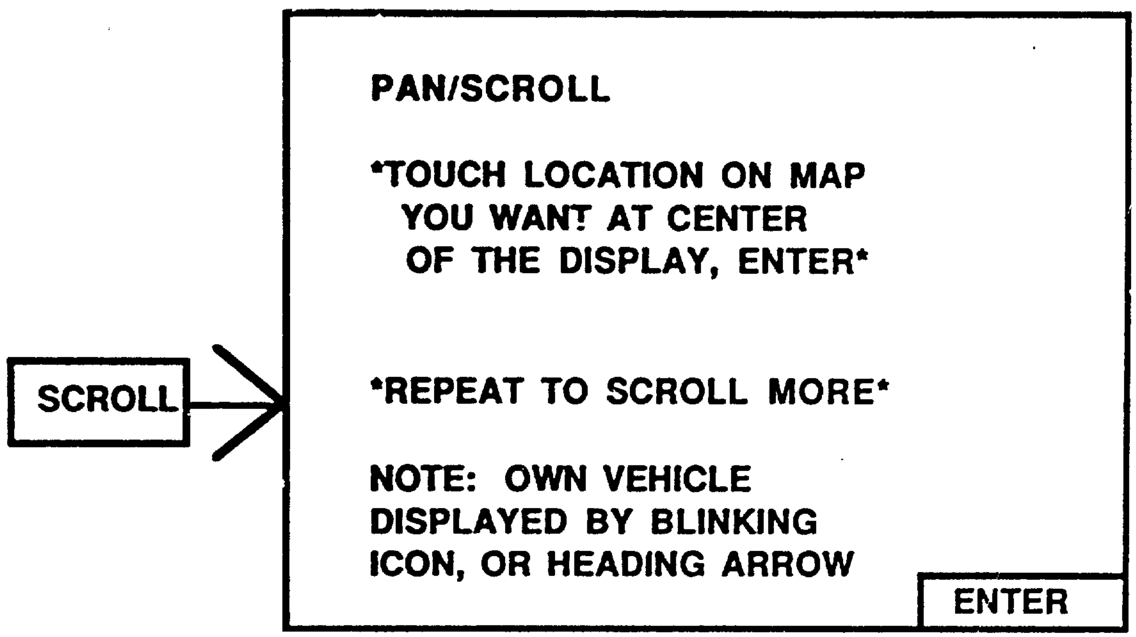

Figure 15. Scroll.

sponding threat elements. For a monochromatic display the friendly symbols are outlined by a single line and the threat elements by double lines (FM 101-5-1).

Again, design for this function was based on the trade-offs between the relatively limited area available on the BMS display for report and message menus and the need for simple, rapid access to graphic functions that are critical to these military communications. Similar to the design of the Measures Function, therefore, the Unit Function provides the user access to the entire friendly and threat symbology included in FM 101-5-1, but requires the user to preselect a subset of these symbols for more immediate display requirements.

This pre-selection process allows the user to precisely specify the unit symbology he wants immediately displayed (e.g., known enemy threats in the area) in the variable menu field of his BMS display. Access to the FM 101-5-1 dictionary of symbols and the preselection process is initiated by pressing the INITIALIZATION key displayed in Figure 16. While complete specification of the initialization process and supporting menu structures are beyond the current scope, it is noted that this initialization is expected to occur prior to actual combat operations as part of the commander's weapon station preparation. Given this preoperational status, the map display region will be temporarily transformed to an extended dictionary display region to allow the user to readily search and select from the dictionary's contents.

As with all user inputs, range control fields will automatically notify the user of input values that exceed any anticipated boundaries. For this preselection process for example, the system will notify the user when the number of unit or measures selected (e.g., 6-10 symbols) exceeds the immediate menu area available to the system. The user will then have the option of adding or deleting any units to this primary subset, followed by the option to select a secondary, or alternate, (e.g., likely enemy threat) subset of unit symbology, and any additional subsets desired.

In addition, it is also recommended that the dictionary include associated weapon system signatures, profiles, and characteristics which might prove particularly useful for less experienced users in cases of attrition and rapid mobilization.

Once the initialization has been completed, the primary set of unit symbols selected by the user is presented in the variable menu area as depicted in Figure 16. The user can then, as indicated by prompts, enter these unit symbols on his map display by first pressing the symbol needed (verified by reverse video) and then touching the map at the symbol location (reflected by the symbol coordinates displayed in the Point Location window). The symbol will blink until the user is satisfied with the unit/element location which is indicated by touching the ENTER key.

As indicated by the next prompt, the user can change the orientation of the unit, the system's default orientation is North, by retouching the map in direction desired and the system verifies this request by immediately

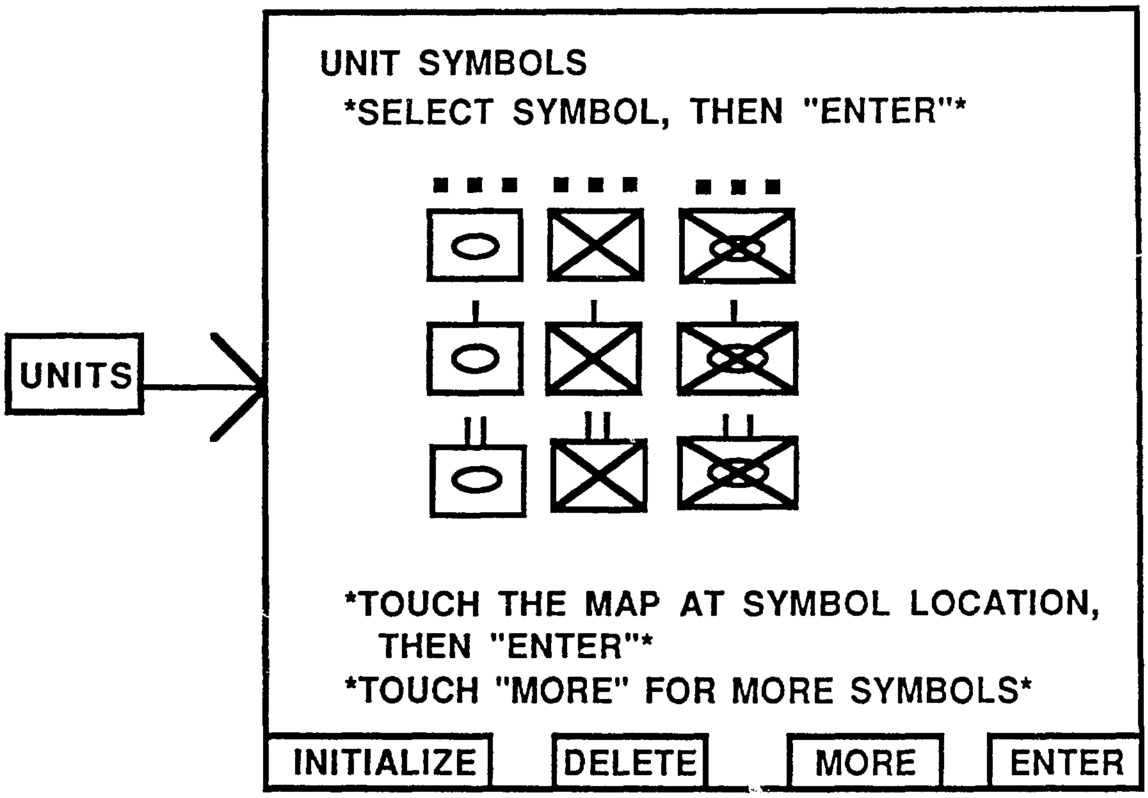

Figure 16. Units.

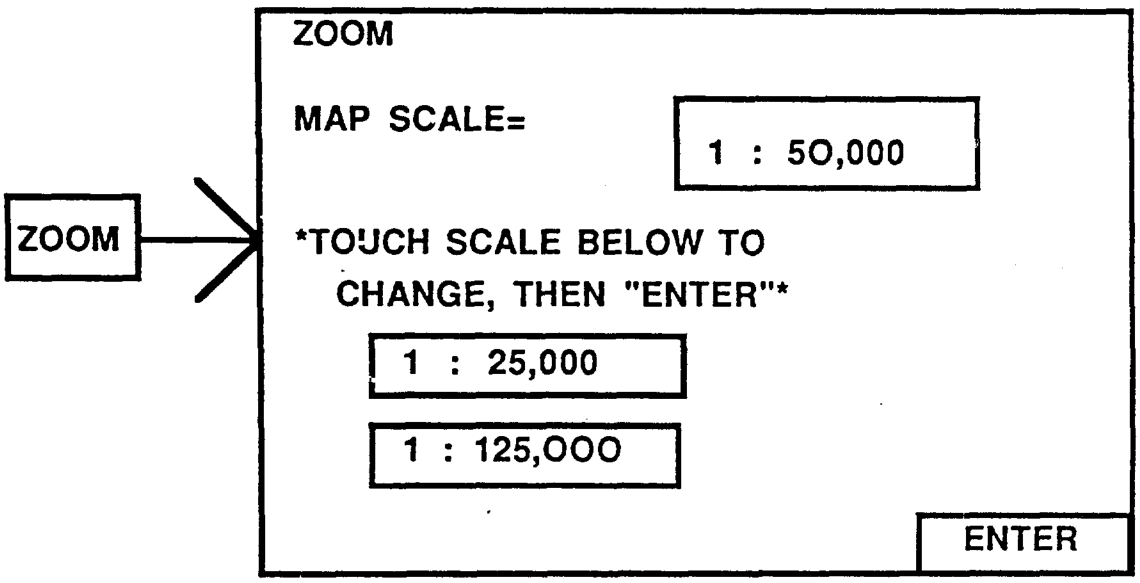

Figure 17. Zoom.

realigning the unit in the direction indicated. If the user is not satisfied with the orientation, retouching the map will repeatedly change the orientation. When satisfied with unit's orientation, the user inputs the unit's orientation by pressing the ENTER key.

The user is then automatically provided, as indicated by reverse lighting, an option to name or label the unit by calling up a soft switch keyboard through activation of the TYPE key. This "keyboard" may require at least partial utilization of the map display area. Utilization of this map area must not occlude the unit being labelled. After typing in the label for the unit the user again activates the ENTER key and the label is positioned on the map display adjacent to the unit in accordance with the fields specifications of FM 101-5-1. The DELETE key allows the user to erase or remove any unwanted units along with their respective label from the map display.

Additional units appearing in the primary set available to the user may be added by repeating the same sequence of steps as indicated by the final prompt. Alternate subsets of unit symbology, preselected by the user, can be accessed by pressing the MORE key. These subsets will displace the primary set in the variable menu area in the order they were constructed by the user. The procedures for inputting these units onto the map display are the same as those for the primary set.

Once the user has added or deleted units from the digital map, the appropriate operational (black) and enemy (red) overlays must be updated.

Zoom

This menu provides the user access to a list of three discrete map scales: 1:25,000; 1:50,000; and, 1:125,000 (See Figure 17). The current map scale is indicated by reverse video and the user requests either of the other two scales by selecting that option. The display size of vehicle icons as well as unit and control measure symbology must vary with the scale of the map.

In addition, the detail of the topographic data appearing in the map display must correspond to the increased detail associated with military maps at the larger scale sizes: 1:25,000; 1:50,000. The military requirements for larger scale topographic displays provide the user a more detailed and precise representation of the surface area including both man-made and natural terrain features (e.g., contour lines at 10-, 20-, or 50-meter intervals). Mere enlargement of the same terrain and man-made features appearing in smaller scale is not sufficient to meet the requirements of small unit commanders. Conversely, the over-representation of the same terrain and man-made features at small scales, that appear in large scale cartography will inevitably result in highly cluttered displays on the relatively limited display surface available to the BMS.

COMMUNICATION GUIDELINES

This section describes a set of BMS functional specifications for communicating the messages--reports, orders, and alerts--required for small unit command and control. The section attempts to provide designers an awareness of the protocols and formats for conventional C^3, and the design challenge to reformat these procedures in a manner that optimizes an automated C^3 system. General design guidelines for meeting this challenge of converting from conventional to automated procedures are first specified. Next the section applies these general guidelines to selected examples of small unit communications: dedicated reports, status reports and the SPOT report. The section also includes selected references that more thoroughly detail the various types of reports and communications required for BMS.

The section will not attempt to provide specifications for every type of military communication such as orders, reports, and alerts nor for every category of communication within each type (i.e., personnel, status, intelligence, and operations reports). Designers and users will need to iteratively develop and evaluate alternative formats and mixes of graphic and textual data that maximize the informational requirements for C^3 and at the same time minimize the senders' and receivers' communication requirements.

Simulation Guidelines

The general design principles for man-machine interfaces--consistency, brevity, flexibility, immediate feedback, and reduced operator workload--must likewise direct the designer's development of automated C^3 procedures and formats. The designer must be continuously aware of the multiple processes and stages that comprise communication: composing, editing, transmitting, receiving, and comprehending the message (Hovland, Janis, & Kelley, 1953; Lasswell & Casey, 1946). The utilization of automated C^3 rather than voice-based modalities raises numerous trade-off issues with respect to each of these stages.

Automated C^3 systems, for example, may effectively separate the composition phase of communication from the transmission phase. With BMS, users routinely select all the informational elements required for a communication such as graphic and text data before any transmission is initiated. After "drafting" this message the user then initiates transmission by activating the SEND key. The message is then digitally burst in milliseconds to the intended receiver, providing the user an extremely rapid and secure medium for transmitting messages.

Voice-based devices, on the other hand, such as the FM radio require relatively extended transmission times that not only compromise security but provide no formal record of the messages' contents. Users receiving any message are generally forced to take immediate notes particularly of the spatial-geographic data such as the grid coordinate locations of units, measures, and target reference points. These notes are generally made in the same alphanumeric format they are received (e.g., six- or eight-digit grid numbers) and then later recoded or spatially plotted onto the users' paper maps or acetate sheets. If the message must be forwarded to another user, as is often the case, the processes must be repeated since no FM record exists.

Vehicle based automated C^3 systems are not expected to provide reliable speech synthesis and recognition capabilities in the forseeable future. To provide digital communications and records, therefore, BMS will require users to communicate alphanumeric data by either selecting preformatted items from a menu of response options (e.g., tank, truck, fixed wing, etc.,) or formatting their own responses via an alphanumeric keyboard, "a typewriter in the tank." Voice-based systems, on the other hand, require no visual search and manual selection among the available response options listed on a menu-based system such as BMS. The communication of selected alphanumeric data items may, therefore, prove more demanding in an automated C^3 system than in a voice-based system such as conventional FM.

The designers' awareness of these trade-offs between conventional and automated C^3, should continually guide their design and developmental efforts for each phase of the communication process. The general communication guidelines presented below and the specific applications of these guidelines presented in a following section attempt to maximize these trade-offs.

Maximize Graphic Capabilities

The primary intent of an automated C^3 system is to provide users a medium that more rapidly, easily, and accurately transmits battlefield information critical to both the planning and execution of military operations, particularly in a combined arms effort. The earlier discussion of BMS map functions stressed that spatial-geographic data is central to C^3 and that military communications via map-base spatial analogs provide a more intuitive, rapid, and accurate mode for this information than voice-based modalities which are characterized by alphanumeric data. Alphanumeric data, however, are still required to supplement map-based information and provide the detailed data necessary to fully interpret tactical intentions and precisely identify and categorize informational elements such as unit and control measure symbology.

The dichotomy between spatial-geographic data and alphanumeric data is emphasized to provide the designer a better understanding of the users' disparate needs and requirements particularly with respect to conventional C^3 procedures. The dichotomy, however, is somewhat arbitrary in that most spatial-geographic data, for example, can be transduced or encoded into alphanumeric elements. Unfortunately, conventional voice-based C^3 procedures have forced soldiers to repeatedly encode spatial-geographic data into alphanumeric elements at the sender's station and then required other soldiers to decode the same elements back to spatial-geographic data at the receiver's station. An extremely simple and critical battlefield communication such as a SPOT report of enemy contact, for example, becomes: "Five T-72 tanks traveling North grid Echo Sierra two, four six, seven, two, one at one, five, five, two, Zulu."

Most military communications, and particularly tactical communications, must convey spatial-geographic information about the geometry of the battlefield and rarely is that information limited to a single coordinate location as in the above SPOT report. More complex battlefield communications which are voice based, therefore, require the repeated encoding and decoding of multiple locations, and even more demanding, the boundaries of circumscribed areas such as battle positions, assembly areas, contamination areas, and obstacles. The voice-based communication of this information is intensely time-consuming, demanding, and error-prone. Graphic communications of spatial-geographic information, on the other hand, are structurally isomorphic to the combat units, events, and processes they represent and require no transfer or recoding into alphanumeric formats. To input the location of the T72 tanks for the above SPOT report, for example, the user simply indicates their position by touching his map display at the corresponding location.

If BMS is to effectively automate and facilitate the command and control process the communication modality must capitalize on the unique capabilities of digital graphic communications. Designers must continuously and iteratively work with the users to exploit this unique capability and both groups must realize that it represents a significant departure from conventional C^3 procedures. This is particularly true for the bottom-up communications such as reports from tank commanders and platoon leaders since conventional doctrinal formats and standard operating procedures (SOP) are designed for voice-based reports (FM).

User-Tailored Options

An overriding guideline for BMS design architecture is the provision of user-specific options. As the battalion-down automated command and control system, BMS must be designed to adapt to the needs of multiple users with differing tasks, areas of interest, and even missions. To expedite the C^3 process, and at the same time establish a uniform software and data base architecture for all small unit BMS applications, the design of the BMS functional capabilities must allow users the opportunity to customize display and control options in a manner that best supports their current duty and mission requirements.

The development of the FM 101-5-1 library of unit and control measure symbology previously discussed (see Map Functions), for example, included initialization stages in which each user first accesses the complete dictionary and then selects subsets of the various unit and control measure anticipated for his communication requirements. The ability to tailor the displays and controls to each user's requirements supports the need for rapid access and execution of the BMS command and control functions and at the same time the library provides a common data base for computer files, processing, and records of small unit communications. Similarly the user's ability to selectively call-up and delete natural and man-made terrain features as well as tactical overlays is intended to provide multi-level users a powerful yet uniform interface for planning, communicating, and executing battlefield operations.

In addition, as noted in the earlier discussion, the BMS display areas and response options are restricted by the relatively limited size (e.g., 9-inch diagonal) projected for the user interface in a combat vehicle. The capability for each user to tailor his display and control functions for maximal utilization of this interface space is a high design priority.

Automated Communications

The highest design priority for BMS is to completely automate as much of the C^3 procedures as possible. For some informational elements--such as routine status reports of fuel, ammo, and weapon system status and location--communications should be completed without any intervention by the user. For other types of information such as intelligence updates of enemy contact detected by battlefield sensor systems which are transmitted from automated systems, the receivers only requirement might be to activate the RECEIVE key. For numerous types of communications which require the distribution of battlefield information among different users and even echelons, the re-transmission of this information should require little more than activation of SEND, RECEIVE, and radio net keys.

Ideally, this automated routing of battlefield communications might be accomplished by knowledge-based systems developed to automatically parse the message (e.g., OPORDs) into smaller subpackets of information directly related to the requirements of different users (e.g., combat, combat service, combat service support, artillery etc.). Near term implementations of BMS, however, are not expected to provide this knowledge base, and human intervention will be required to ensure that users receive only the information needed. The goal for designers nevertheless is to minimize the procedures for distributing this type of information. The need for doctrinal changes to traditional C^3 procedures quickly surfaces, and for this example may require that the conventionally-fixed format for writing and issuing an OPORD may require modifications that would more readily support automated or partially automated parsing and distribution of battlefield data.

Automated Information

One of the most critical design requirements for an effective automated C^3 system is to routinely and automatically include informational elements such as call signs and authentication procedures which are required for every battlefield communication. While the majority of C^2 communications will require that users compose their own messages, unlike the automated communications just discussed, a primary objective of the design must be to automatically include informational elements like sender and vehicle identifiers, date and time groups, and authentication checks, that currently belabor conventional communication requirements. Data from the National Training Center (NTC), for example, suggest that call signs and authentication procedures account for over 50% of all time spent on the communication nets during company level exercises (Phelphs & Kupets, 1984). Similarly incoming messages should be time-and user-stamped for both receipt and acknowledgement procedures, and a distribution log thus maintained for battlefield data which might be subject to multiple transmissions.

Automated records of this type will prove invaluable for determining the validity (i.e., confidence estimates) of intelligence data, establishing the archival logs of prior communications, developing rules for purging intelligence overlays of outdated information, and identifying multiple reports of the same information by correlating across time, location, and source files. In addition, this automated information will serve in documenting actual small unit communication patterns for the later development of more automated distribution capabilities and hierarchical command filters for restricting informational access to selected user subsets.

Automated Encryption

Command and control requirements in voice-based systems are exacerbated considerably when the Security of Communication Activity Level (SCALE) exceeds I which assumes "that all communications will be passed in the clear" (FC 71-6, p 1-7). At higher levels such as SCALE II and III the encoding and decoding tasks seriously degrade C^3 efficiency and effectiveness. Since BMS communications require precomposition before they are transmitted, transmission times are significantly decreased. When this reduction is coupled with digital burst transmission and the SINCGARS (single channel ground and airborne radio subsystems) radio interface, BMS should provide a much more secure communication modality (particularly when automated user identification routines are implemented). If encryption is required, however, the design should include automated procedures for encoding and decoding battlefield information. By eliminating the need for user-based encryption, BMS will have significantly reduced the C^3 burden and increased both its efficiency and effectiveness.

Automated/Repeated Transmission

Conventional C^3 procedures require that users directly participate in the transmission process, they serve as the input device for voice-based communications. Data from the NTC, again for company level exercises, demonstrate that small unit commanders must wait, on the average, 28 seconds simply to gain access to the nets to begin a transmission (Phelphs & Kupets, 1984). Because the user is also a transmitter in voice-based systems, the user must not only attend to the communication while awaiting access to the net but also during the actual transmission. And since most messages are composed of multiple transmissions (to reduce transmission time and maintain security) and multiple waits to access the net for each of these transmissions, the transmission process requires a substantial investment of time and attention by the user.

The BMS design must provide the user a medium for minimizing the time and attention required for FM transmission. By allowing the user to compose communications independently of their transmission, BMS provides a "fire-and-forget" quality to the transmission process. BMS transmissions are initiated by the user touching the SEND key and the system must then automatically direct, monitor, and repeatedly transmit the message to the designated receiver until the message has been completely recorded by the receiving station.

Because the message is recorded in a digital format and stored by the sender's system, the transmission can be repeated automatically in the event that part or all of the transmission is lost due to any of the various types of interference that impede military communications (e.g., static, background noise, garble, distance, terrain obscuration, jamming, etc.). Nearly a third of all small unit transmissions experience interference at the NTC (Phelps & Kupets, 1984). The digital burst of BMS (versus the extended vocalization time of FM) will not only reduce these interference rates, but the design must ensure that BMS will automatically rebroadcast messages that are lost or partially interfered with, without any additional user tasking.

Vehicle-Based Functions

The BMS guidelines and functions previously discussed have provided designers the tools and specifications for many of the supporting functions needed for developing the REPORT functions required. This report has focused on the vehicle-based BMS systems of the lower echelons within the battalion, and in particular the vehicle-based BMS interface. For vehicle-based systems, the overriding design philosophy for BMS is: Keep it simple. From this perspective, the vehicled-based user is primarily a receiver, not the generator, of the more complicated communications such as the OPORD composed and issued from a battalion tactical operations center (TOC). And the battalion OPORD is a refinement of a higher echelon mission that the TOC has received. It is important that designers, and sponsors, of lower echelon automated C^3 systems are aware of this informational context within which BMS operates. It allows vehicle-based commanders to focus on fighting the battle, by providing them the informational "tools" to rapidly and easily generate their own communications.

In contrast, the format of the OPORD is an intricate and relatively complex structure which can only be outlined in a five paragraph statement: situation, mission, execution, service support, and command and signal. The order itself is composed of numerous subparagraphs of highly detailed data and formats, and is supported by various annexes that correspond to the overlay types previously discussed under Map Functions. The BMS-based terminal at the battalion TOC must support the preparation, refinement and issue of this order. The vehicle-based BMS terminals should be designed to receive this data--and ideally, only those portions of the order necessary for the user to understand his commander's concept of the operation, and the user's role in support of this operation.

The construction of the operational overlays and the supporting graphic and control measures will primarily be performed by nonvehicle-based systems with larger displays, processors and data bases. The BMS users will generally be the recipients of this information, but not the originators. Nevertheless, the BMS makes digital transmission and reception of this information possible and helps to ensure that lower echelon users receive command and control data in a more timely, uniform, accurate, and secure manner than is possible with conventional command and control procedures.

This informational context will greatly reduce the vehicle-based users' requirements to generate their own overlays and graphics from scratch. Their utilization of BMS for planning will primarily require supplementation to this data base, the informational context will have been provided by other users. Platoon leaders, for example, will generally only need to refine the graphics provided by upper echelon users. The platoon leader in a defensive mission, to continue the example, might more precisely orient the graphics provided for his battle position "goose egg" and realign his sectors of fire. But the original military symbols for these position and sector graphics should be generated onto the map display by personnel in the battalion TOC using their nonvehicle-based systems and then transmitting these overlays to the platoon leaders.

Considerable effort has already been invested in the design of higher echelon automated C^3 systems, and most notably the Maneuver Control System (MCS) with which the BMS must interface. Designers of BMS should be aware of this relationship and the design concepts employed in the MCS, but the current task does not include the development of a BMS-MCS interface. It is important to maintain this perspective for a number of reasons including the development an integrated Army Command and Control System. The issue is primarily raised at this time, however, because the design of a vehicle-based C^3 system independently capable of formatting an OPORD on a small screen interface is more than challenging--and fortunately not required for this report's focus on vehicle-based BMS.

C^3 Documentation

Designers must extend these guidelines to support all small unit command and control communications which are primarily classified as orders, alerts, and reports. Key reference documents for identifying conventional small unit command and control requirements are: FC 71-6, "Battalion/Brigade Command and Control," and FC 17-17, "The Division 86 Tank Battalion/Task Force SOP, Coordinating Draft." The 71-6 document provides the most definitive reference for identifying the data elements and formats required for orders including: Operation (OPORDS), Warning Orders and Fragmentary (FRAG) Orders; and alerts such as Air Defense, Readiness Condition Status; Nuclear, Biological, and Chemical (NBC); and incoming graphics, messages, and reports. The FC 17-17 document provides a definitive reference for the data elements and formats required for reports including: Personnel (Red), Intelligence (Green), Logistics (Yellow), Operations (Blue), as well as Shell and NBC.

Supporting documentation for the specification of small unit command and control requirements is provided by Standard Operating Procedures (SOP) Manuals: FC 17-16 "The Division 86 Tank Company SOP," Coordinating Draft, and FC 17-15-3 "Tank Platoon SOP." These SOP manuals will provide designers an excellent summary of the data elements and formats required for bottom-up communications within the battalion.

One additional reference that designers need to be familiar with is "IVIS: Intervehicular Information System" a draft document generated by the Directorate of Combat Developments, Spring 1987. The IVIS document is USAARMC's specification of the command and control functions required for a base-line automated C^3 system which is envisioned as the starter-set for BMS. The IVIS document provides an excellent summary and overview not only of the base-line operational command and control requirements for users, but also the materials required for training aids in support of preoperations checks and planning. In addition, the document specifies the requirement for an IVIS tutorial and provides designers overviews of the subsystem integration of M1A1 components required for bit/bite diagnostics as well as maximal utilization of the automated C^3 interface.

Guideline Applications

The following section demonstrates applications of the guidelines of the above communication functions. The applications are limited to selected reports—dedicated reports, status reports, and the Spot report. The intent of this section is to exemplify utilization of the guidelines and demonstrate the potential reduction in command and control requirements as a result of automated C^3 systems.

Dedicated Reports

In fast moving tactical situations, timely reporting of enemy actions is critical. The prototype BMS provides dedicated report keys for the most important of these reports. Dedicated report keys allow the user to generally bypass the menu structure of the BMS REPORT function and relay critical information quickly. The dedicated report keys are exemplary applications of how automated C^3 systems might provide user-based real time updates of battlefield information throughout the battalion, greatly reduce the users' requirements for communicating this information, and render BMS an effective force multiplier.

These are abbreviated report functions which in bypassing the more formal REPORT formats also bypass some of the doctrinal and SOP elements currently required. Each of these report types must, therefore, also be included under the REPORT functions in a nonabbreviated manner that contains the data elements and formats currently required by doctrine and SOP. The dedicated report keys provide the user an alternative format for expediting these communications in a manner that quickens the decision and response cycle. When more detailed information is required, or as time allows, users will exercise the option to submit this information under the REPORT functions.

Contact. When enemy units are encountered the user can rapidly initiate a report of enemy contact by activating the CONTACT key. Pressing the CONTACT key accesses the menu appearing in Figure 18 which directs the user to first "fix" the enemy units by touching the map at their location. This results in a blinking icon appearing on the map display at that point and the coordinate location of that point appearing in the Point Location window at the bottom of the map display. Retouching the map results in relocation of the blinking icon.

The user is then prompted to identify the type of enemy unit contacted by selecting from the subset of enemy units previously selected during the INI-

TIALIZATION phase (see Units under Map Functions). It will be recalled that the user has selected this subset of potential enemy units on the basis of his assigned mission and supporting intelligence data. The subset, therefore, reflects the known or likely enemy units which might be encountered in this area. Upon selection of a unit type the blinking icon on the map display converts to a blinking symbol corresponding to the unit selected. If the unit type is not present in the initial subset, the user is directed to select MORE which accesses the alternate subset of unit types previously selected during INITIALIZATION.

The user is then directed to indicate the direction of movement (if the unit is not stationary) by touching the map adjacent to the unit in the direction the unit appears to be moving. A blinking arrow or vector symbol appears on the map corresponding to the direction indicated, and this direction can be adjusted by retouching the map in another direction. If the user is satisfied with the accuracy of the data depicted on the map, the user is directed to touch the ENTER key and blinking of the icons is terminated. The user then communicates this data by touching the SEND key.

Call For Fire. One of the most critical and time-dependent communications for small unit commanders is the request for indirect artillery fire. Conventional procedures for communicating this request are complicated by (1) extrapolation of enemy location (six-digit, polar plot, shift), (2) formats requiring five additional informational elements (identification of observer, warning order, target description, method of engagement, method of fire and control), and (3) selection of the Fire Support net. The Call For Fire dedicated report function drastically reduces these requirements by providing the users an alternative function for rapidly requesting artillery fires. Again users must be provided a more doctrinally complete format for Call For Fire under the REPORT function.

By pressing the CALL FOR FIRE key users access the menu appearing in Figure 19 which directs them to "fix" the enemy units by touching the map at their location. Again the subset of unit types appears in the variable menu area and the second prompt allows users to describe the enemy in a manner identical to that under CONTACT. Subfunctions such as relocation of enemy units, access to alternate subsets of units, and data entry are also identical to that under CONTACT; but these elements may again be omitted at user's discretion. Activation of the CALL FOR FIRE key also switches the net to the Fire Support Officer (FIST) automatically. At a minimum the user can request indirect fires by touching the (1) CALL FOR FIRE key, (2) the map at enemy location, and (3) the SEND key.

NBC. Activation of the NBC key sounds an alarm that alerts the unit to mask in protective gear. Once the user touches the ENTER and SEND key, a similar alert is sent to neighboring units. In addition, activation of this key accesses the menu appearing in Figure 20 which directs the user to first specify the type of agent, and then the location of the contamination upon the map display. A blinking military symbol for that agent appears on the map display and if the user is satisfied with the accuracy of the data, blinking is terminated and data entered by touching the ENTER key. Activation of the SEND key completes this abbreviated NBC report which again must have a more doctrinally complete format under the REPORT function.

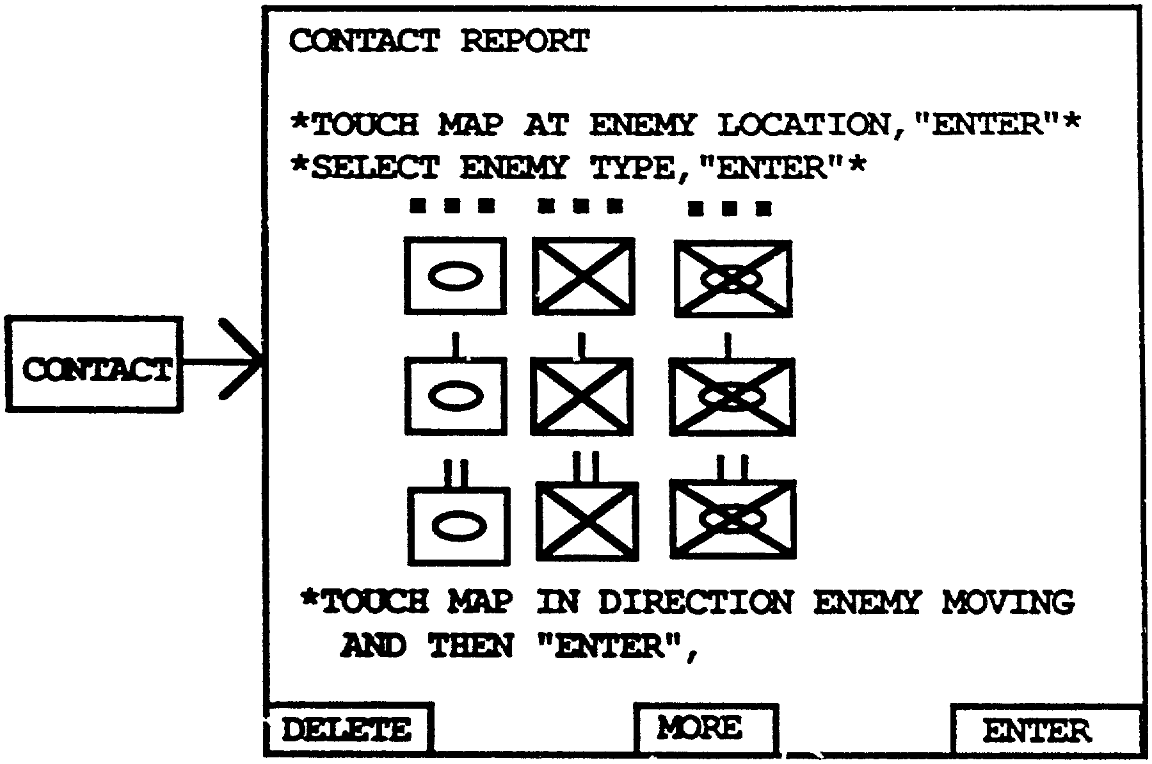

Figure 18. Contact report.

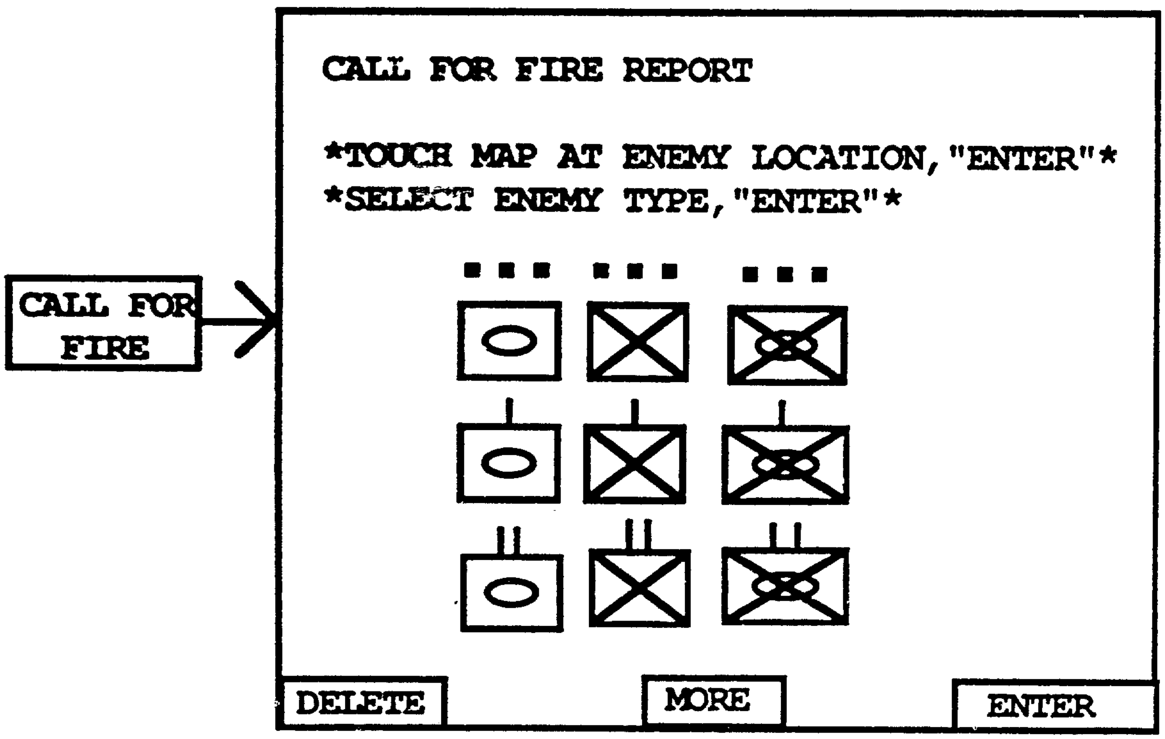

Figure 19. Call for fire report.

Status Reports

The Status function provides the current operational status of the user's unit personnel, vehicle, and equipment. All status information is to be initially presented to users in color-coded formats (i.e., black, amber, green, or blue) which correspond to the relative operational status of selected components. Designers are referred to 71-6 "Battalion/Brigade Command and Control," 1 March 1985, for specifications of these color-coded formats. In addition status information should be maintained in alphanumeric formats which provide more precise data about component status for issues of resupply and Combat Service Support.

Figure 21 presents a main menu listing some of the required status submenus (e.g., personnel, vehicle, and equipment). For example, the submenu of Equipment Status, Figure 22, presents a list of vehicle components which are color coded to reflect current operational status. Pressing one of the menu selections gives the same information for the subsystems of the tank. For example, Figures 24 through 25 are supporting submenus to Figure 22, that provide status information for selected vehicle components. Figure 26 provides personnel status data that must be updated by the user. The TYPE function allows the user to edit the reported status. Summary data from all tanks are sent to the platoon sergeant's tank and form one of the automatic components of the SITREP.

Reports and Orders

Activation of the REPORTS function accesses a main menu as depicted in Figure 27 which provides the user a list of the primary categories for communicating and reviewing command and control data: Orders, Alerts and Reports. Application of the communication guidelines will be presented for the SPOT report.

Spot Report. The users activation of the REPORTS key accesses the menu shown in Figure 27 which provides a list of the major types of C^2 communications. By selecting Reports from this list and then ENTER, as indicated by the prompts, the user accesses a menu of report types as depicted in Figure 28. The report options included in this list are based on either user-level default items automatically provided by the BMS, or they are the report types selected by the user as his primary set of reports during an INTIATIALIZATION procedure identical to that described for Units and Measures. The library of report types and required data formats and elements are specified by the three user-specific SOP Manuals previously cited. From the menu of report types the user selects, for this application, the SPOT report. The SPOT reports is used when known or likely enemy units have been observed.

After entering his selection of the SPOT report, the user is provided the menu appearing in Figure 29 which lists various types of enemy units and a numeric keypad for indicating the type and strength of units observed. The units depicted in this menu are the same as those selected by the user as his primary subset of known or likely enemy units during INITIALIZATION. Again, by activating the MORE key, alternate subsets selected by the user may be

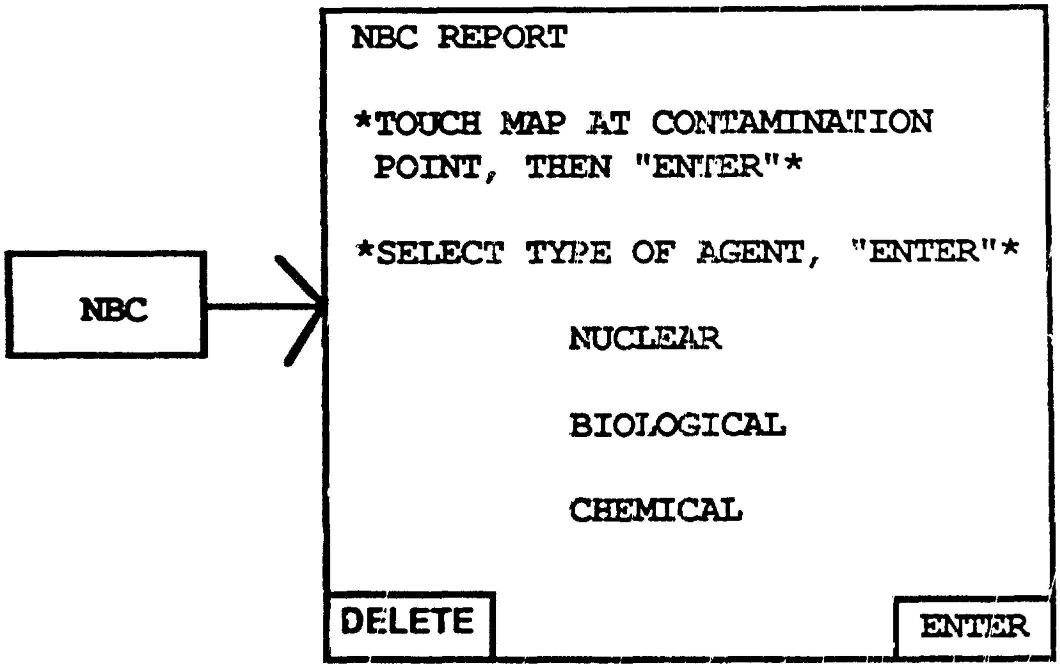

Figure 20. NBC report

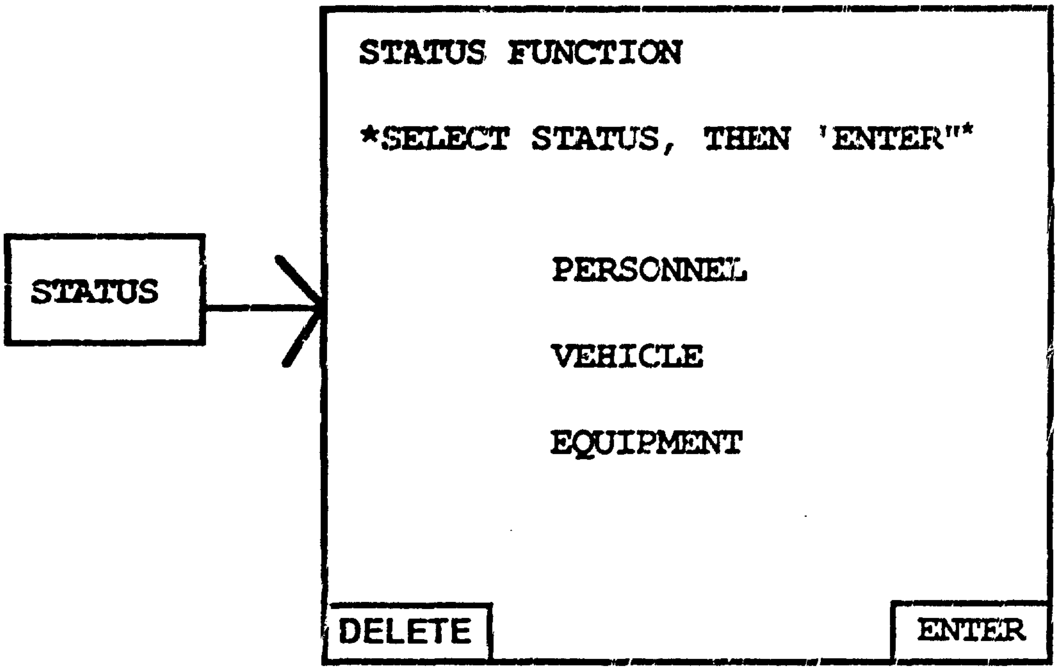

Figure 21. Status menu.

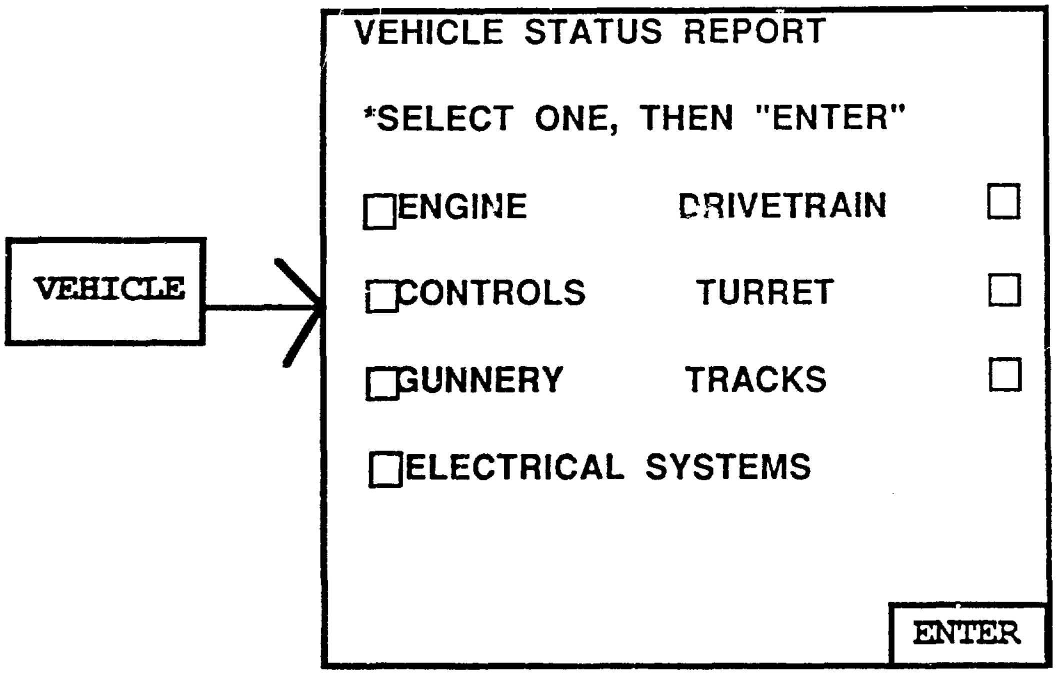

Figure 22. Vehicle status.

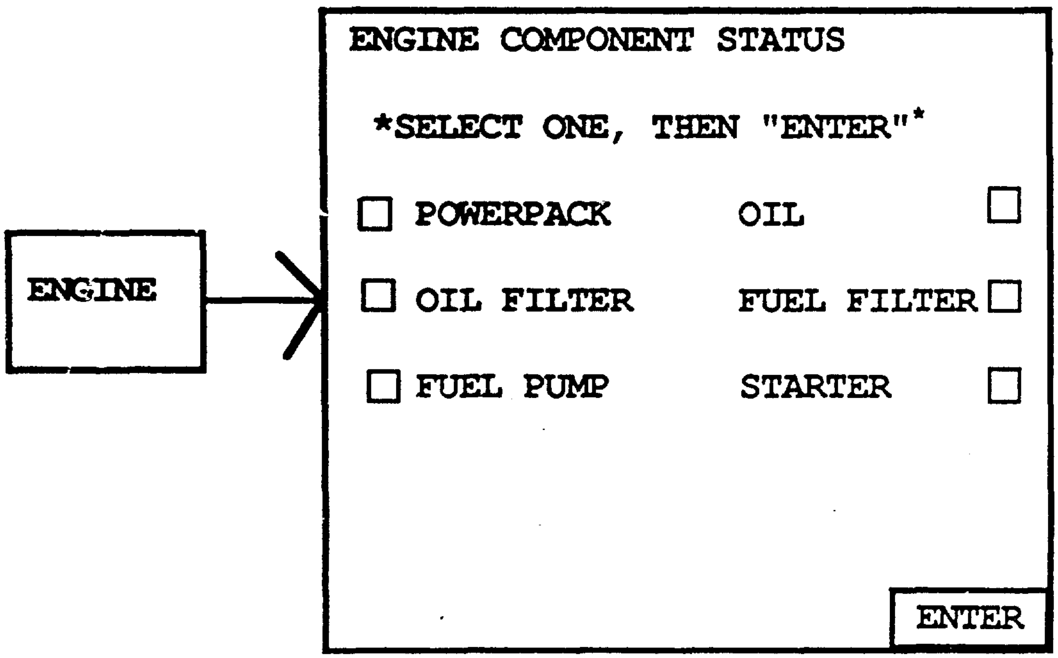

Figure 23. Engine components.

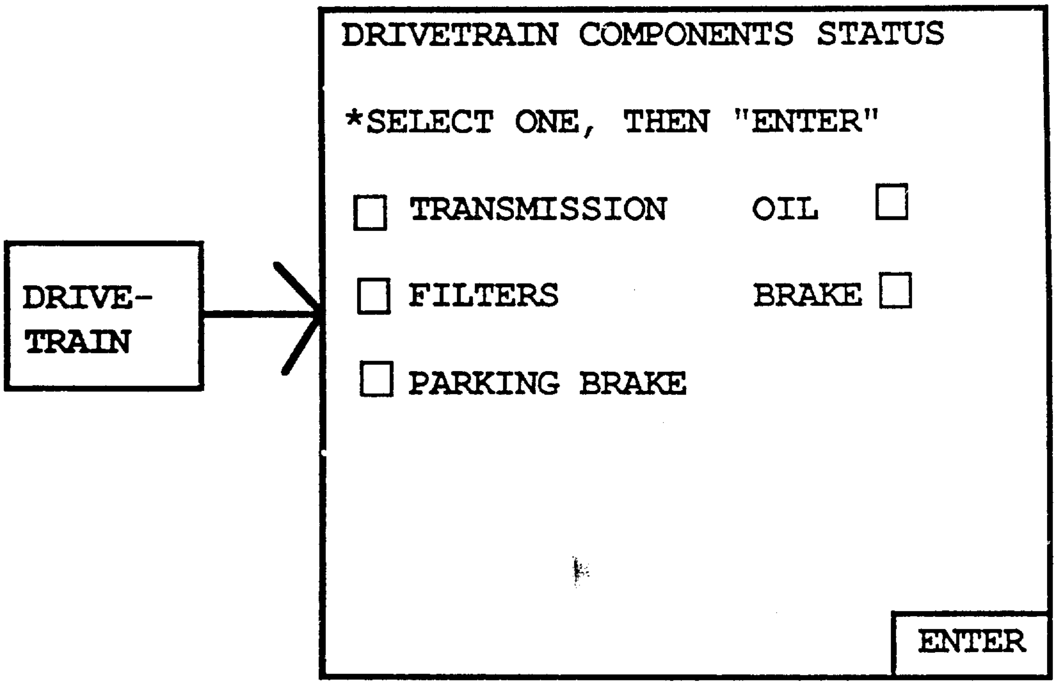

Figure 24. Drivetrain status.

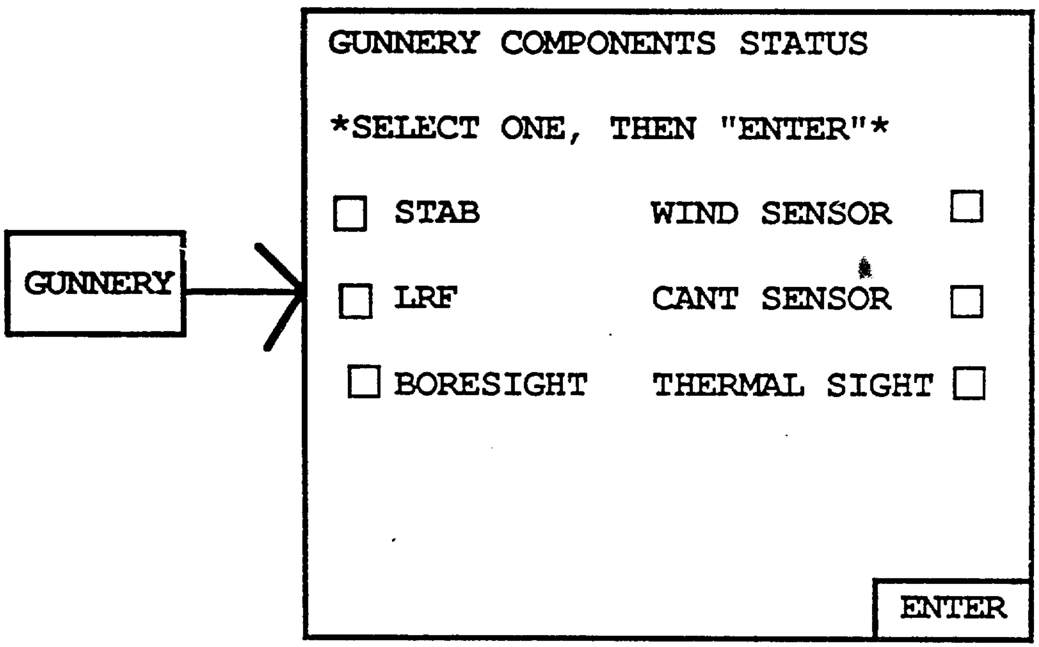

Figure 25. Gunnery components.

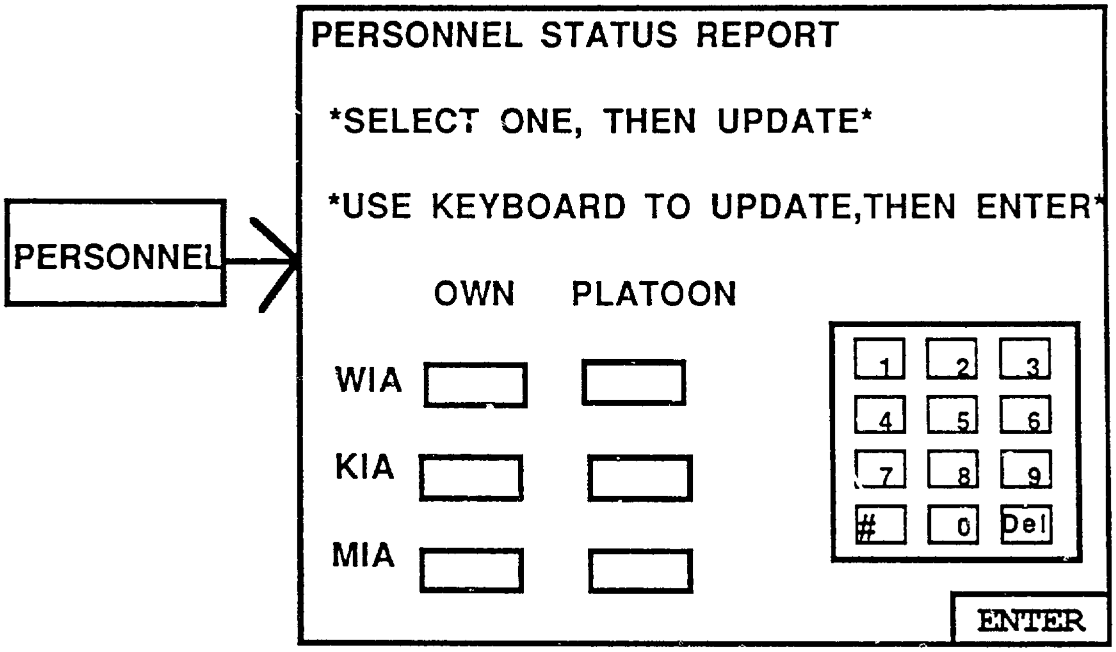

Figure 26. Personnel status.

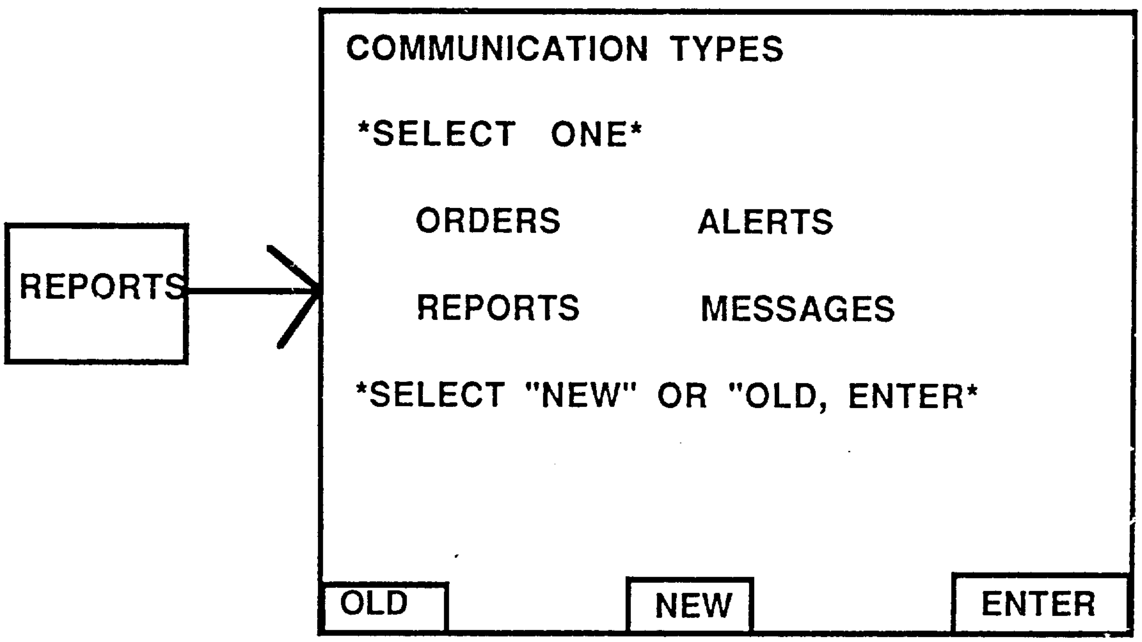

Figure 27. Communication types.

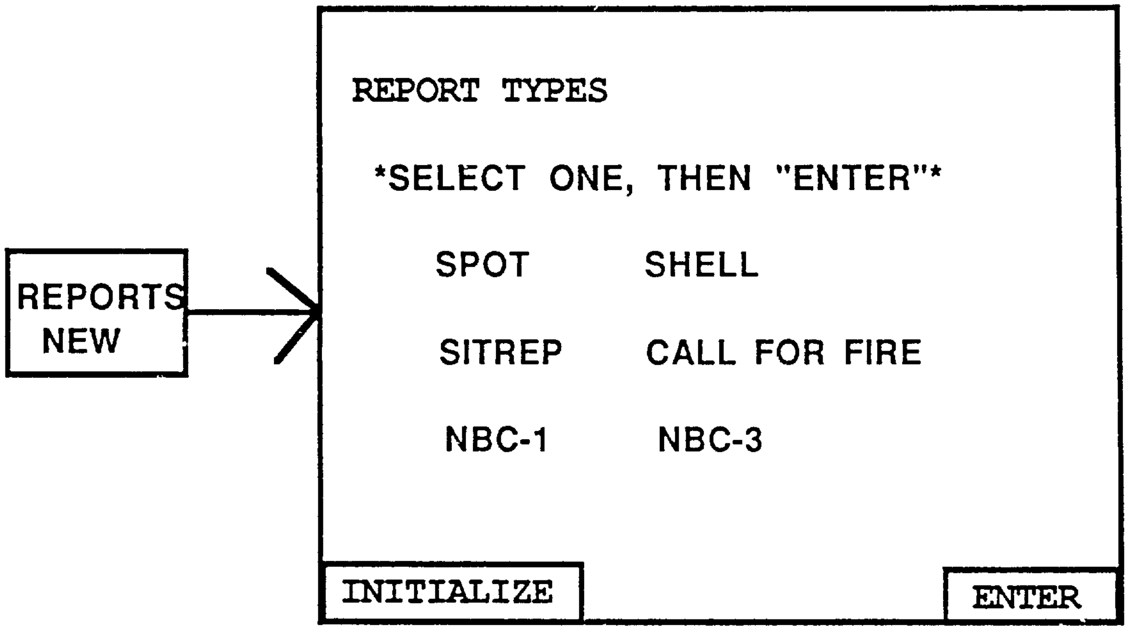

Figure 28. Report types.

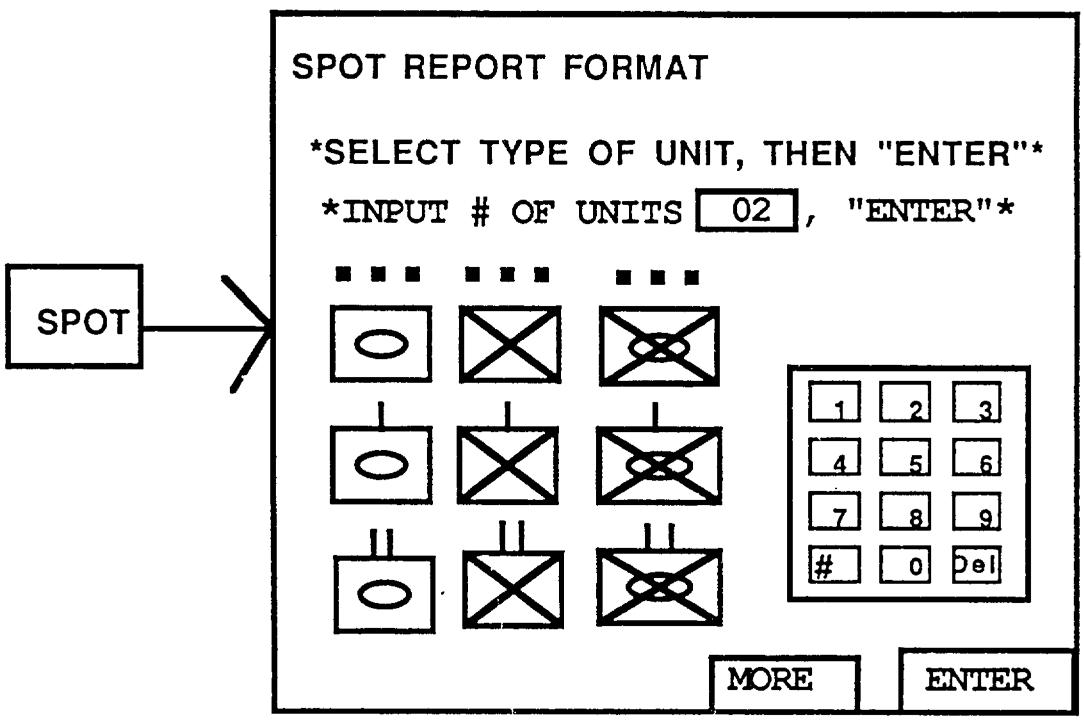

Figure 29. Spot: Type, strength.

accessed. After selecting the type of enemy unit observed, reflected by reverse video, the user is prompted to specify the number of units detected via the numeric keypad. Users inputs via the keypad are echoed back in the data field window and the user can edit his entry with the CLEAR and DELETE keys. When the user is satisfied with the accuracy of his data, activation of the ENTER key automatically accesses the Activity and Location menu depicted in Figure 30.

The Activity and Location menu provides a format for specifying enemy and own activity as well as enemy location. As indicated by the prompts, the user first selects the appropriate activity levels for enemy and then own units, and then is directed to indicate enemy location by touching the map display. This location is reflected back to the user by a blinking icon and the entry of enemy coordinate data in the Point Location window. When satisfied with the data, the user touches ENTER.

If the user indicated that enemy units were "Moving" under the Activity and Location menu, selection of the ENTER key automatically accesses the menu in Figure 31 requesting the direction and speed of enemy movement. The prompts for this menu direct the user to indicate direction by touching the map display adjacent to the enemy unit symbol previously entered (with orientation adjustments the same as discussed before under Units and Measures), and then to use the keypad for indicating estimated speed of movement. If the user selected "Observing" or "Engaging" under the Activity and Location menu, however, the ENTER key activation of that menu bypasses the Direction and Speed menu (Figure 31) and automatically access the Summary menu appearing in Figure 32.

The Summary menu provides the user the opportunity to review and edit the SPOT report before transmission. If satisfied with the SPOT report data the user touches the SEND key to transmit the message. If the user wishes to edit the information in any of the data fields the user selects that field, as indicated by the prompt, and the system accesses the supporting menu (28-31) from which this data was obtained. After editing the supporting menu and touching ENTER the user is returned to the Summary menu. When editing is completed the user touches the SEND key to transmit the SPOT report.

POSNAV GUIDELINES

The POSNAV system is an integral component for supporting many of the BMS automated C^3 functions. POSNAV's ability to monitor own-vehicle location and heading completely automates some of the most critical and demanding requirements for small unit maneuver forces.

When POSNAV capabilities are integrated with other vehicle subsystems cumulative effects are realized, particularly with respect to the communication of battlefield information. POSNAV linked with the laser range finder (LRF) data, for example, provides the capability for automatically determining and communicating the location of enemy targets. When combined with the automated report capabilities of BMS this integration provides the user an extremely efficient technology for directing combat support requests such as

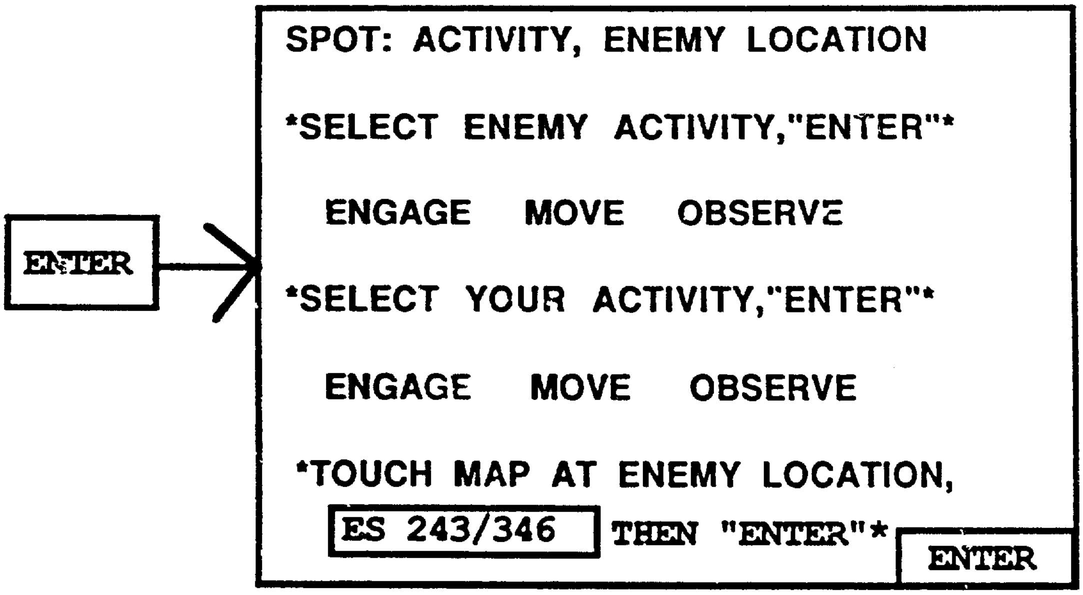

Figure 30. Spot: Activity, Location.

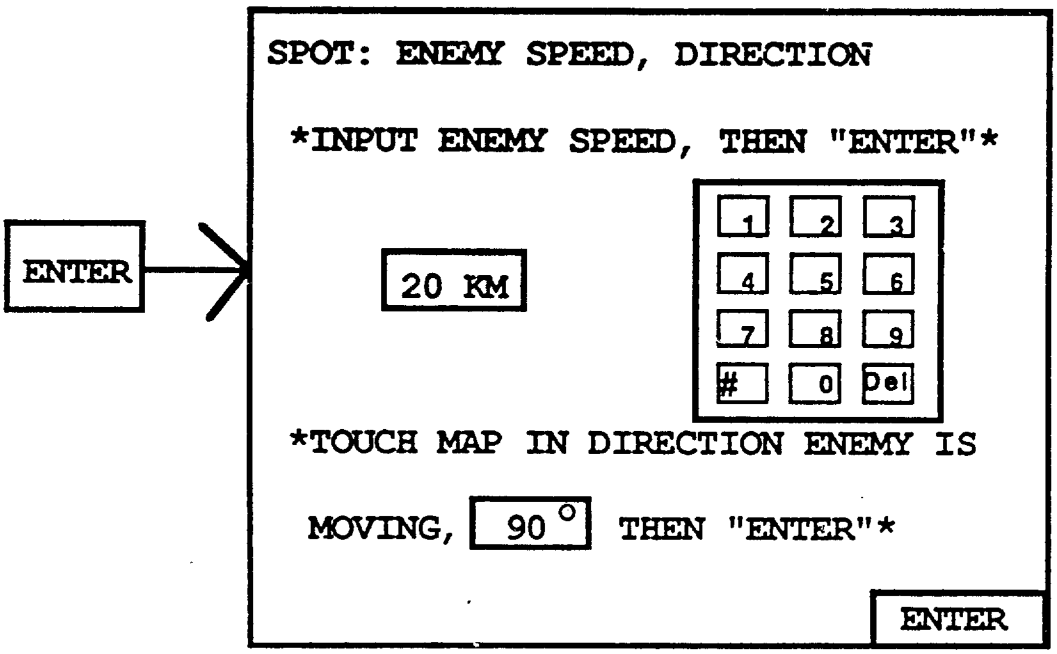

Figure 31. Spot: Speed, direction.

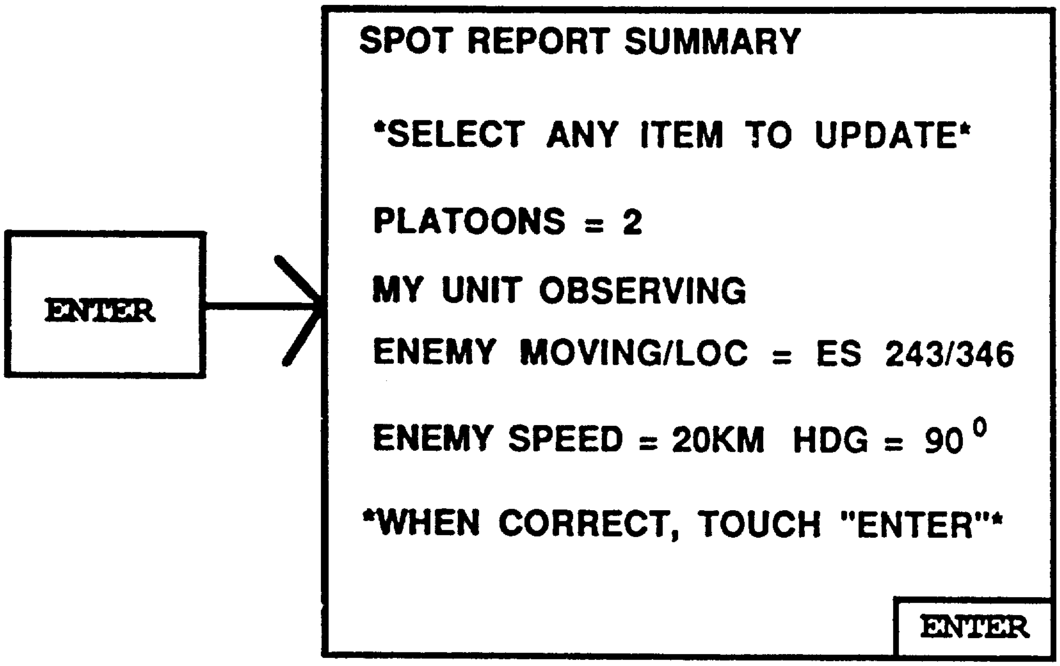

Figure 32. Spot report summary.

the call for indirect artillery fires and monitoring the location of all friendly forces. Combined with the graphic communications features of BMS, the POSNAV provides the geographic correlates for ensuring that operational orders and supporting overlays are rapidly and accurately dissimenated to all members of the combat force.

POSNAV Specifications

The following section summarizes the users' functional specifications for POSNAV. These specifications are taken from the IVIS (1986) document previously cited and designers are referred to this document for additional detail.

Position Location
* 100M CEP (circular error probable) or 2 percent (68 percent PE) of distance traveled, whichever is greater.
* Update requirement no greater than one update per hour.
* Average mission length 7-10km without update.

Heading Azimuth
* System 1 degree root mean square.
* Driver's steer-to information within + or - 3 degrees.
* Pitch/roll up 20 degrees.
* Operating latitude + or - 65 degrees.
* Manual initialization allowed, north seeking desired.
* Drift 1 degree per hour.

Waypoints/Objectives
* Capability to preset a minimum of six waypoints or objectives.
* POSNAV must provide navigational information to any of these predesignated points individually or sequentially.
* Approximate time to waypoints/objectives must be computed and displayed.
* Navigational information must be available to the driver through the steer-to indicator located in driver's compartment.

Update Function

Activation of the dedicated NAV key in the bottom section of the BMS interface accesses the main menu of available POSNAV functions as depicted in Figure 33. The menu provides the user three main functions: Digital Update, Map Update, and Route Designation. Selection of any of the items presented in this menu followed by touching the ENTER key accesses the supporting functions discussed in the following sections.

There are two modes for data entry of vehicle location. The user may enter coordinate data digitally via the numeric keypad depicted in Figure 34 or the user may elect to touch the map at the actual coordinate location of the vehicle. Numeric entry may allow for greater precision than the map-based entry mode, but will presumably increase the input requirements. Both modes should be provided for the BMS prototype.

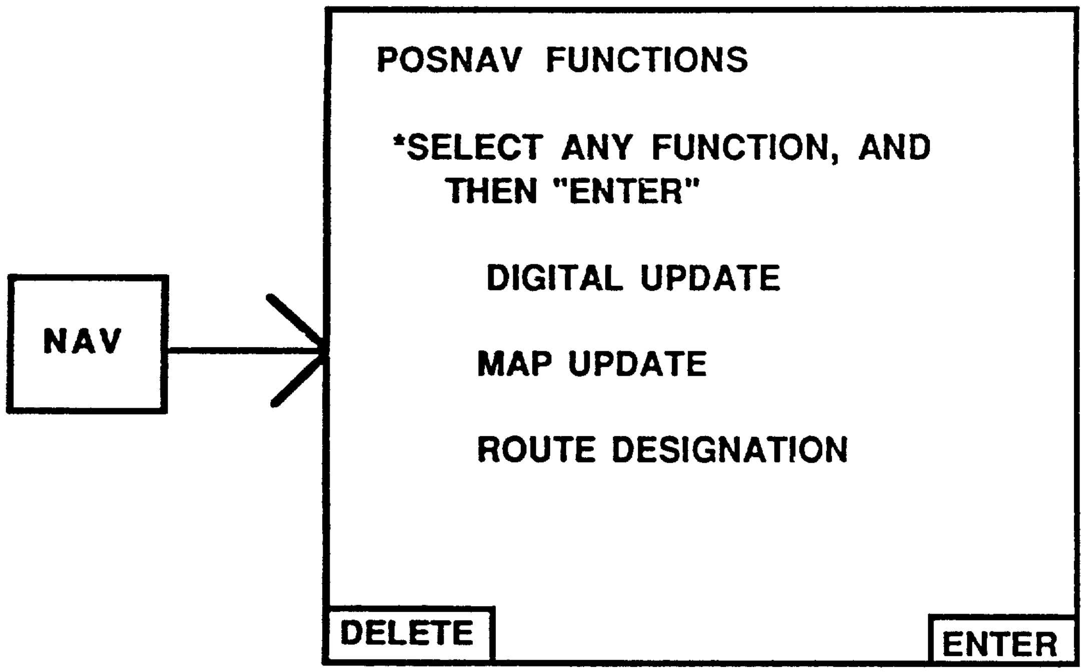

Figure 33. POSNAV functions.

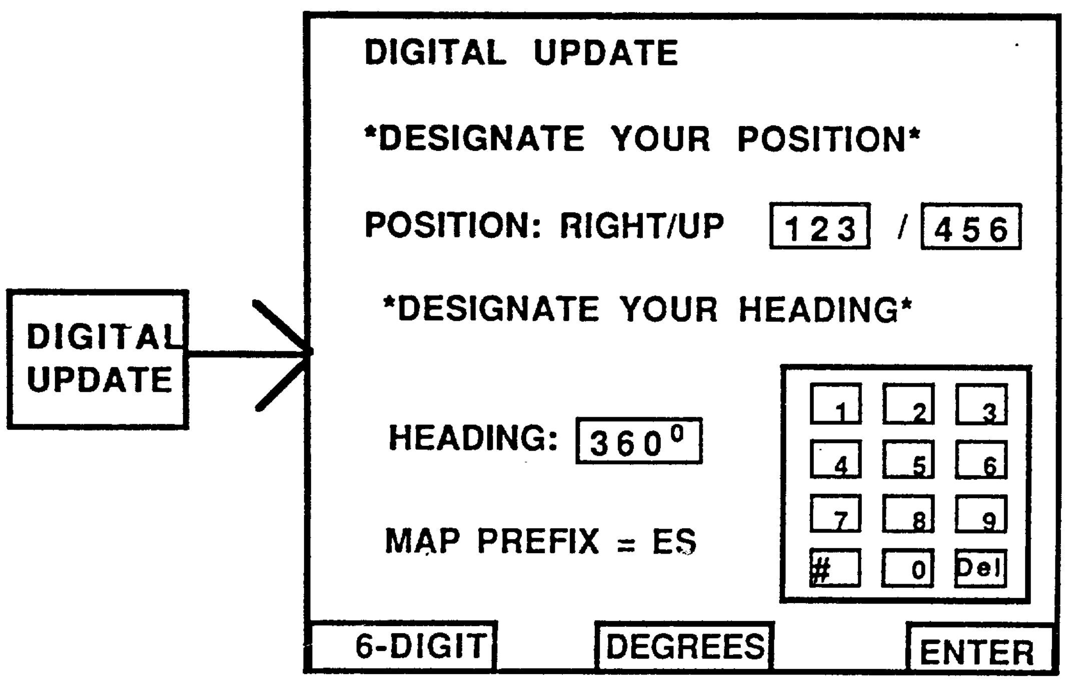

Figure 34. Digital update.

Digitally-Based Entry

As indicated by the initial prompt in the Digital Update menu, the user first selects the Position option for updating the vehicle's POSNAV system. This selection is verified by reverse video of the Position label and its corresponding data entry block. The data entry format for vehicle position has been separated into two data fields--Right and UP. Users familiar with the Universal Transverse Mercator System (UTM) are aware that the "Right" data field corresponds to the West/East axis and "Up", the South/North axis. Users are trained to think "Right/Up" in determining UTM grid-based locations. The Right/Up labels are included to better ensure transfer of train ing, and are consistent with the design guideline of user-based vernacular and data formats in the BMS interface.

Similarly the default value for location data is six-digits since this is the resolution normally used by the Armor force. The option for eight- to ten-digit formats is provided by the DIGIT key at the bottom of the menu. Users requiring finer resolution are directed to press the DIGIT key which then displays an eight-digit format, an additional press results in ten-digits, and a final press reverts back to the six-digit format. UTM prefixes (e.g., ES, PN, etc.) used to identify the map sheet are automatically provided by the BMS once he has scrolled the map (see Map Functions) to the area he is located.

Activation of the Position label is reflected by reverse video of only the "Right" label and its corresponding data field to ensure that coordinates are entered in a "Right/Up" order. For additional feedback, the horizontal (West/East) grid reference axis on the map display begins to blink to ensure that the user is directed to the appropriate axis. When the user has completed data entry in this field (e.g., three-digits), the "Up" label and data field are automatically highlighted in reverse video and the vertical (South/North) grid reference axis on the map display begins to blink. These design features are included to minimize the probability of users transposing the coordinate digits and/or reversing the coordinate axes: two types of user entry errors extremely common when inputting coordinate data as noted by LTC. T. Blasche (personal communication, June 8, 1987). They are recommended for digital coordinate entry under any of the BMS functions.

Pressing the keys on the numeric keypad enters the data in the highlighted data entry block. If too many digits are entered in the "Up" field, given the operating digital resolution format (six-, eight-, or ten-digits), an audio beep is emitted. Similarly if the inputted location does not correspond to the area currently depicted on the map display an audio beep is emitted along with textual feedback to that effect. Pressing the DELETE key once, deletes the last digit in the data field highlighted and allows it to be reentered by the keypad. Pressing the DELETE key twice deletes the entry in the highlighted field and allows it to be reentered by keypad or touch screen. When the user has completed inputting the Position data a blinking icon of the vehicle is automatically depicted on the map, the map is updated to position this icon at the center of the display, and the inputted coordinates are displayed in the Own Location/Heading window at the lower left corner of the map display.

When the user selects Heading, the label and data field are highlighted and vehicle heading may be entered via the numeric keypad. The default heading format is a three-digit entry of degrees. Access to a four-digit mil format is provided by the key labeled DEGREES in Figure 34. By touching this key its label changes to MILS as does the label for Heading data above the numeric keypad. Entry in the data field is constrained, in a manner similar to that for Position (i.e., auditory beeps), for any errors detectable by the system. When the user has completed inputting the Heading data the blinking icon of the vehicle's hull is automatically oriented on the map in the direction inputted, and the inputted data displayed in the Own Location/Heading window at the lower left corner of the map display. When the user has completed the update of Position and Heading data, a touch of the ENTER key updates the POSNAV system and the vehicle icon terminates blinking.

Map-Based Entry

For map-based entry of vehicle location the user, as indicated by the prompt in Figure 35, merely touches the map at the location of his vehicle. A blinking icon of the vehicle is automatically depicted on the map, the map is updated to position this icon at the center of the display, and the corresponding coordinates displayed in the Own Location/Heading window at the lower left corner of the map display and in the "Right/Up" data fields in the variable menu.

For more precise positioning the user may request a more sensitive input capability by touching the PINPOINT key. The PINPOINT function temporarily recalibrates touch inputs to a resolution-level that equates roughly to 100 meters per finger width for Position data, and 5-degrees for Heading data. By iteratively touching the map and monitoring the coordinates or degrees displayed the user should be able to quickly and precisely position the vehicle. When the user is satisfied with the accuracy of the location data, a touch of the ENTER key stores the data and the Heading label begins blinking. The user is still operating under the PINPOINT function and after touching the map adjacent to the vehicle icon in the direction desired, the blinking icon of the vehicle's hull is automatically oriented on the map in the direction indicated, and the direction displayed in the Own Location/Heading window at the lower left corner of the map display and in the Heading data field.

The MILL/DEGREE and DIGIT keys operate as described under the digital entry mode. When the user has completed the update of Position and Heading data, a touch of the ENTER key updates the POSNAV system, turns off the PINPOINT function, and the vehicle icon terminates blinking.

Route Designation Function

The Route Designation function is accessed from the main NAV menu by pressing the Route Designation selection and the ENTER key. This function allows the user to indicate a route or course of movement by marking a series of waypoints on the map display. The term waypoint was selected to provide a generic descriptor. Checkpoints, for example, serve a similar function, but

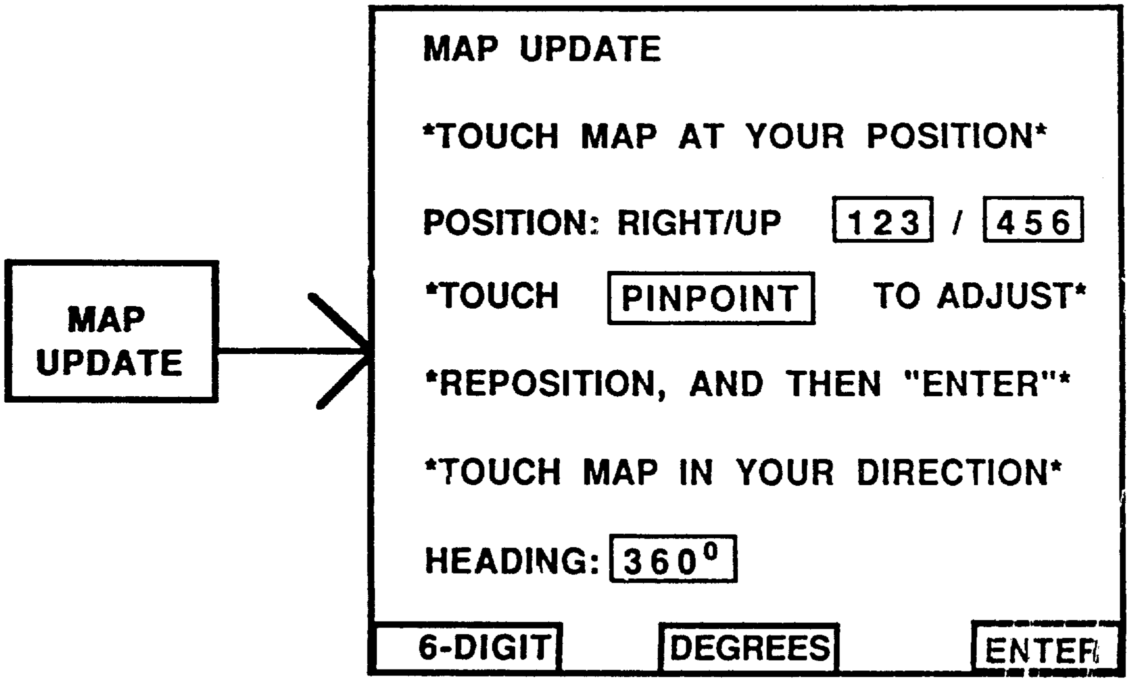

Figure 35. Map update.

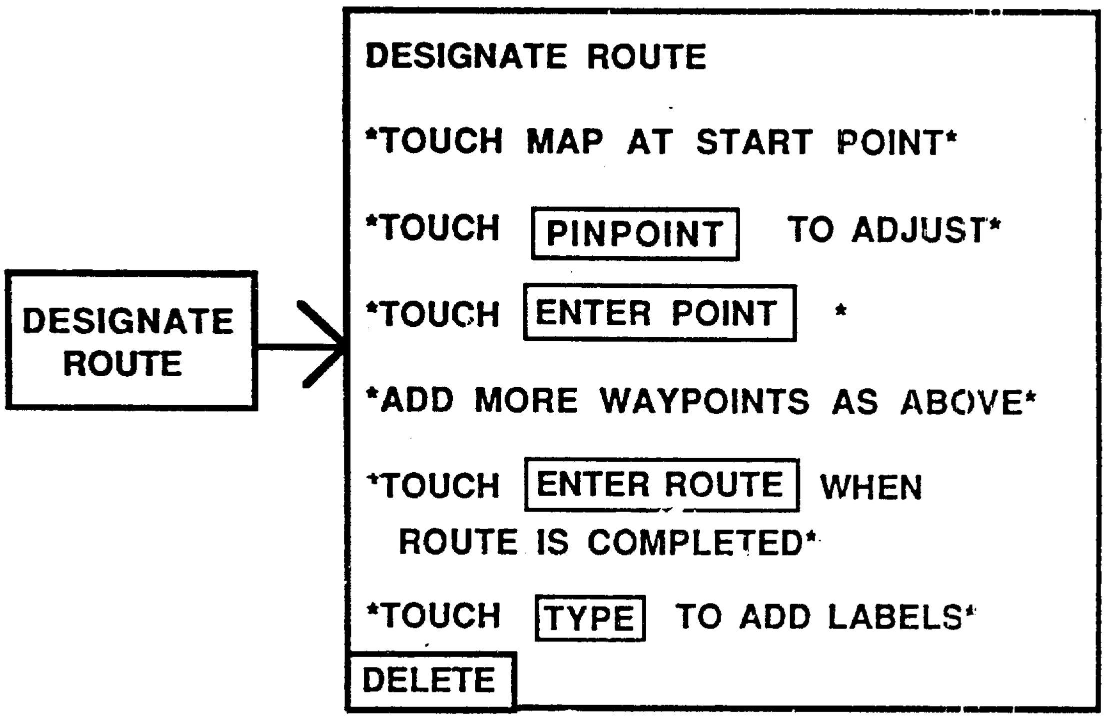

Figure 36. Designate route.

also imply the need to report back on current location. Figure 36 shows the Route Designation menu.

As indicated by the first prompt, the user is directed to touch the map display at the location of the start point for the route being marked. A blinking checkpoint symbol appears at the location designated by the user. In addition, the six-digit coordinates of the waypoints's location are displayed in the Point Location window. The PINPOINT function operates as described under the Update Function, and if the user is not satisfied with the location of this waypoint he can touch PINPOINT, and then the map to reposition the waypoint. When the user is satisfied with the waypoint's location, the waypoint is stored by touching the ENTER WAYPOINT key. The icon terminates blinking and the label SP (for Start Point) appears on the map adjacent to the waypoint icon.

The user is then directed to indicate the location of all subsequent waypoints in the route being designed by iteratively touching the map to position the waypoint and then the ENTER WAYPOINT key to store it. As each waypoint is stored it is assigned a default label (i.e., WP 1, WP 2, etc.). Waypoints must be entered in actual route sequence as indicated by the prompt. The intended route is also indicated by dotted lines, or "legs" that link the waypoints along the designated route.

To delete any of the waypoints previously entered the user touches the waypoint to be deleted, and it begins blinking. After verifying that the correct point has been selected, the user touches the DELETE key and that waypoint disappears from the map display. In addition, the connecting legs to that waypoint are deleted and legs are redrawn to connect the remaining waypoints. When the user has completed construction of the route and is satisfied with the location of all the designated waypoints, he presses the ENTER ROUTE key.

Pressing the ENTER ROUTE key formally enters this route into the system memory, and results in a route label (e.g., R 1) appearing adjacent to the route on the map display. Each route and waypoint is thereby uniquely identified, and users can readily specify route and individual waypoints in their communications with others. This also ensures a system identifier for each route/waypoint which is entered into a route log. The system must keep track of this log in assigning new route and waypoint labels to ensure that all labels are unique.

In addition, the user has the option to provide his own label to routes and waypoints. As indicated by the prompt, the user wishing to assign his own labels is directed to touch the TYPE key. By touching the TYPE key the user brings up the soft switch keyboard which may require at least partial utilization of the map area section. Utilization of the map area does not occlude the route being labeled. Activation of the TYPE key also brings up a list of the current route and waypoints with their default labels in the variable menu section as depicted in Figure 37. Each route and waypoint is followed by a blank field into which the user can type the specific names and labels desired.

Any waypoint label field in Figure 37 that is currently activated can be edited by touching its label. When the user has completed his labeling he is prompted to touch ENTER. The user is only required to provide identifiers for the waypoints he selects. Upon activation of the ENTER key the labels designated are depicted on the map display adjacent to their respective waypoints and the default labels are removed.

Driver's Display

The POSNAV system provides steer-to information to the driver that primarily indicates whether or not he is on the correct course to the next waypoint. Figure 38 depicts the driver's read-only display. The vehicle icon in the display rotates to indicate the vehicle's current direction with respect to the next waypoint which is depicted at the top of the display. Additional data fields provide the driver with information about the vehicle's current location and heading, the route and waypoint identifiers, the waypoint's coordinates, and the distance to the waypoint.

BMS ENHANCEMENTS

The BMS guidelines and specifications presented in the report represent a mid term estimate of the automated C^3 capabilities anticipated for vehicle-based C^3 systems. As noted in the introduction, this report addressed mid term expectations rather than limit its scope only to the near term capabilities proposed for IVIS, the first generation of automated C^3 systems projected for Armor combat vehicles. The goal was to define C^3 system characteristics, and particularly the user interface to the system, that would provide combat developers and researchers a flexible and powerful test bed for investigating both current and future soldier performance issues with respect to automated C^3 systems. Central to this goal was the development of a simulation prototype that could be systematically assessed, modified, and reassessed in a task-loaded, force-on-force combat environment such as that provided by SIMNET.

This section discusses several enhancements anticipated for far term automated C^3 systems. These enhancements will be included in subsequent upgrades to the simulation-based BMS prototype being developed, but are beyond the scope of this effort.

Artificial intelligence (AI) may be the most significant enhancement anticipated for automated C^3 systems. The capstone of an AI system would provide an optimal tactical decision (e.g., plan of action) to the commander/operator that is based on integrated knowledge bases, expert rule-based protocols, and real-time intelligence data (Harris, et al. 1985). Once a tactical decision has been formulated and approved by the commander, the AI system should be able to automatically formulate (e.g., operations order, fragementary order) and transmit this information in detail appropriate to both lower and upper echelons. As the execution of this plan unfolds, such as the crossing of phase lines or contact with the enemy, the AI system should be automatically monitoring, updating and reanalyzing the tactical

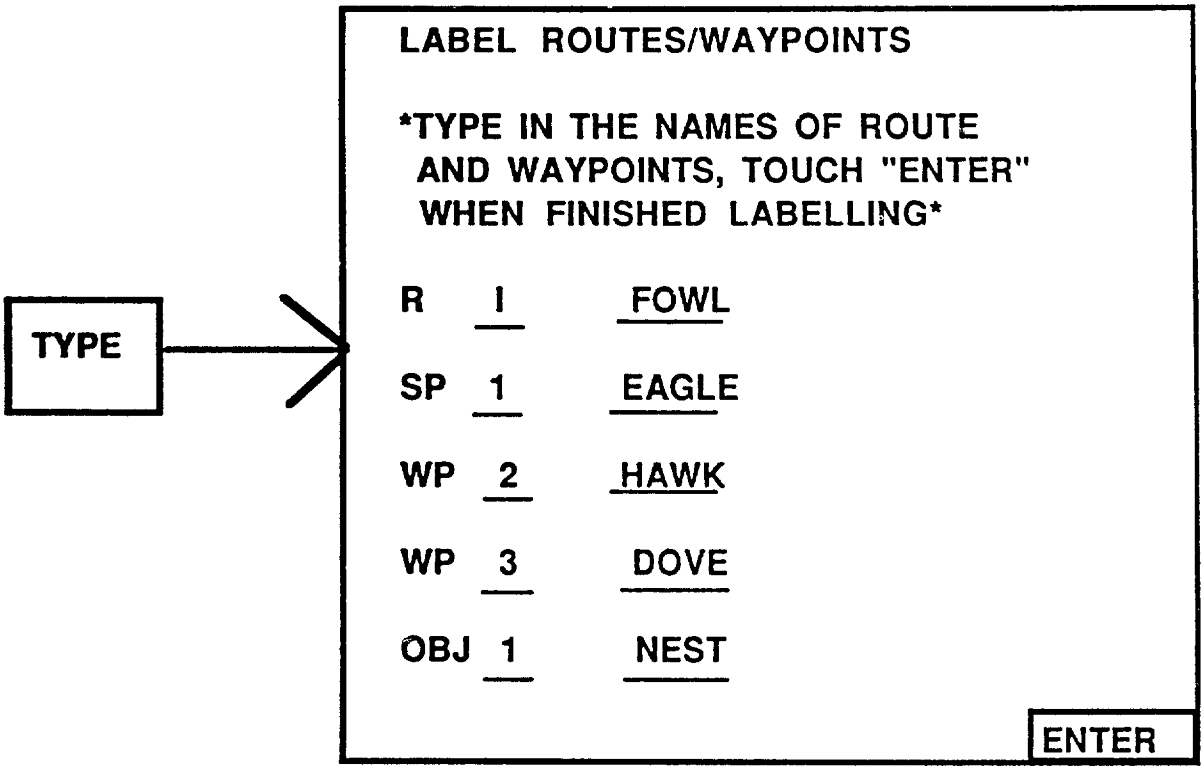

Figure 37. Label routes and waypoints.

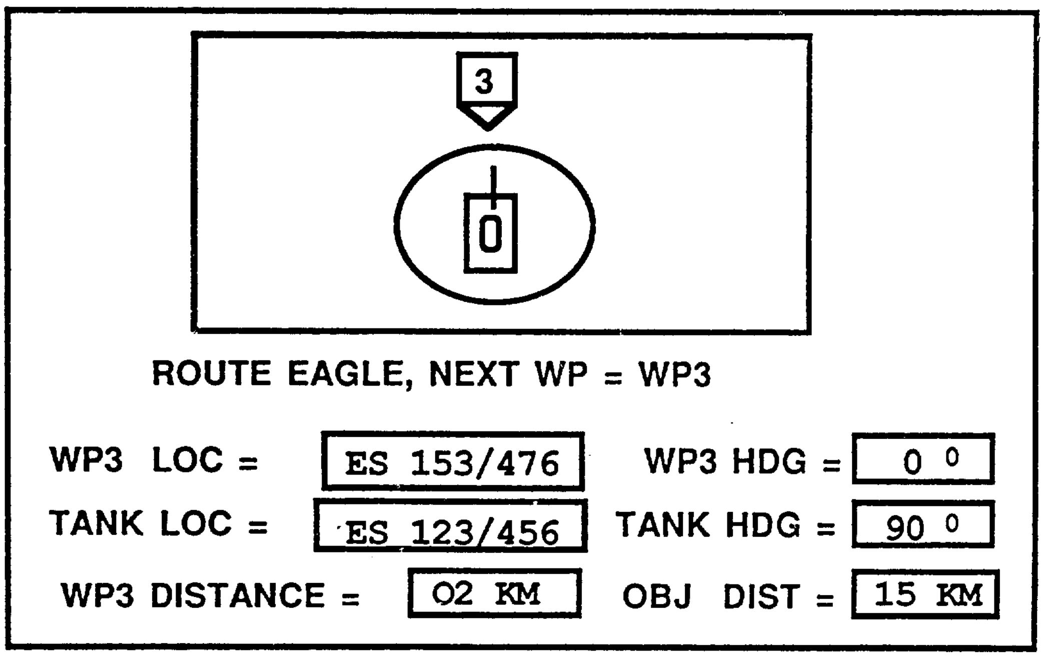

Figure 38. Driver's display.

situation. While the introduction of AI into BMS or a related vehicle-based C^3 system is regarded as a long term enhancement, a simulation-based BMS prototype such as the one proposed in this report, will provide an excellent medium for implementing and testing AI capabilities.

Voice input technologies are regarded as an extremely important enhancement for vehicle-based C^3 systems. Vehicle commanders are also fighters. They are directly involved in both monitoring and fighting the battle. In manning their own vehicle and weapon systems, their hands and eyes are already preoccupied. The current requirement for a touch, or even light pen, device for inputting C^3 information may prove a significant disadvantage in comparison to voice-based C^3 inputs on conventional radio equipment. As noted in the prior discussion of input devices, when voice input technologies have sufficiently matured to meet the demands of the stressful and noisy Armor environment, they should be readily included in this prototype and assessed as a potential BMS enhancement.

An additional enhancement to BMS, not fully developed in this report, is an increased emphasis on subsystem integration. To maximize the potential of BMS for automating C^3 functions, subsystem integration is a paramount consideration. For example, BMS linked with a Commander's Independent Thermal Viewer (CITV) could provide map-to-sensor and sensor-to-map correspondence that might significantly increase the effectiveness of both systems. The Tank Automotive Command (TACOM) is currently pursuing the development of the Standard Army Vetronics Architecture (SAVA), and it is anticipated that system integration will be a cornerstone of the Block II and Block III improvements to the M1 tank. As this architecture is defined, this simulation-based C^3 prototype system should be upgraded to reflect this architecture to assess its effects on soldier performance with respect to C^3 task requirements.

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